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TECHNICAL REPORT ARLCD-TR-77006

MALFUNCTION INVESTIGATION OF THE XM935 POINT DETONATING FUZE

JOHN F. KOSTKA

APRIL 1977

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER
WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This report documents the effort in the investigation of the premature of a 60 mm XM720 HE projectile with XM935 PD fuze on 4 September 1975 at Aberdeen Proving Ground during a safety certification test. The fuzes utilized in this test had "short" pull wires, which were assumed to have been purged from the system. A previous incident involving fuzes with "short" pull wires caused a premature function at Lone Star Army Ammunition Plant during a jolt test in June 1974. An in-depth study of

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20. Abstract (continued)

mortar fuze safety was initiated to determine the cause of these incidents of premature fuzes.

Presented are the design analysis, design approach, design concepts, and test results.

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Dr. Joseph F. Shelley, Army Research Office Investigator, rendered valuable assistance and expertise in performing the extensive physical analysis of the failure mechanism involved in the XM935 malfunction, and in the organization and interpretation of test information.

Marvin H. Hauptman, physical scientist, Picatinny Arsenal, was primarily responsible for the physical analysis of the fuze failure mechanism and associated data reduction and comparison.

Gertrude Weintraub, mathematical statistician, Picatinny Arsenal, was primarily responsible for the design, development, and evaluation of a test plan to determine the individual sensitivity and comparative sensitivity of the XM935 fuze to arm after being dropped.

INTRODUCTION

A premature function of the M567 point detonating (PD) fuze occurred during a jolt test at the Lone Star Army Ammunition Plant in June of 1974. A second premature, attributed to sequential rough handling, occurred in September of 1975 during a safety certification test at Aberdeen Proving Ground. The complete round configuration used in the safety certification test was an XM720 HE projectile with an XM935 PD fuze with short pull wire.[1] This report was prepared in response to these two events.

The major objectives of this study were:

1. To establish the basic causes of the failures which caused the two premature armings.

2. To specify corrective design changes.

3. To demonstrate the effectiveness of these changes in

   a. New production M567 fuzes

   b. Renovation of M567 stockpile items

   c. The Lightweight Company Mortar (LWCM) Program (which utilizes the XM935 fuze)

An analytical and experimental program was implemented, with the following components:

1. Analysis of static failure loads and energy required to subvert the delay pin and pull wire.

2. Analysis of static failure loads of the original and several candidate firing-pin designs.

3. Static load testing of the fuze elements and complete fuze assemblies.

---

[1]The M567 fuze referred to in this report is used with 81mm mortar cartridges. The XM935 is a 60mm version of the same fuze. A history of the design development of both fuzes is contained in Appendix A.

4. Jolt, drop, and sequential rough handling testing, both to requirements and to failure.

In the tests to requirements, such as in MIL STD testing, the outcome is given in terms of pass or fail. The tests to failure were conducted to establish safety margins and the relative strengths of the various design modifications. Table 1 is a summary of the tests conducted.

Table 1

Summary of testing

	No. of tests to requirements	No. of tests to failure
Jolt	526	271
Drop	85	490
Static load		247
Sequential rough handling	560	144
Ballistic	224	
	1395	1152

DESCRIPTION

The M567/XM935 PD fuze is a delay arming, superquick or delay functioning, point detonating mortar fuze for use on 81mm cartridges HE M374 and WP M375 and 60mm cartridge HE XM720. The fuze contains two independent setback locks and utilizes a pull wire to provide protection against forces which may resemble a firing signature, such as malfunctioning of the parachute drop safety test. In addition, the fuze is capable of being fired fully armed (if armed in a normal fashion) and still functioning on impact. An exploded view of the M567 fuze is shown in Figure 1. A summary of the different design configurations of the two fuzes is given in Table 2.

Arming of the fuze is initiated by two setback locks (consisting of two pins, two springs, and two balls) which individually detent the firing pin and the delay element striker. A spring-loaded slider, containing a superquick (M98) and delay (M76) detonator, is, in turn, held out of line by a pyrotechnic-delay-actuated arming pin and the firing pin. With sufficient setback loading, the spring-loaded firing

pin is released to move forward against a windshield after cessation of these setback loads. On setback loading, the striker is released and initiates the pyrotechnic delay element which, in turn, releases the slider after a burn time of 2.6 seconds. The slider then moves to align either the super-quick or delay detonator with the firing pin and lead assembly. At impact, crushing of the windshield pushes the firing pin into the detonator, thus initiating fuze function.

The fuze has three distinct safeties. These include:

1. The pull wire

2. The arming pin in the delay element holder

3. The firing-pin tip interlocking with the slider

The function of these safeties is to prevent motion of the slider, which aligns either detonator with the firing pin. By preventing this motion, an aligned firing train cannot be created. The definition of slider motion for arming is shown in Figure 2. A separation distance of at least 0.025 inch between the edges of the lead and detonator holes is required.

The original fuze design utilized short pull wires. These were later replaced by long pull wires. The term "pull wire" in this report is understood to mean the long pull wire.

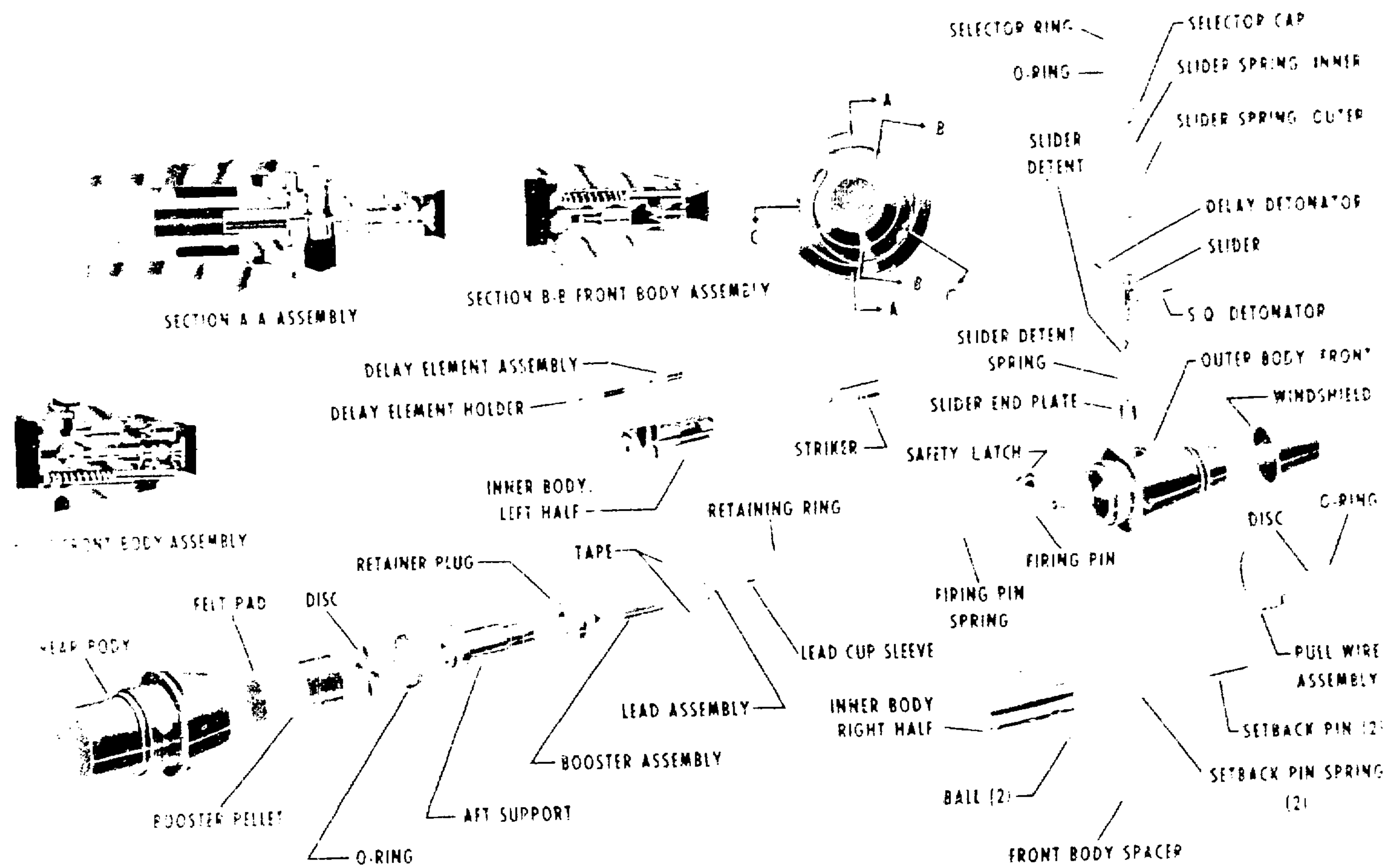


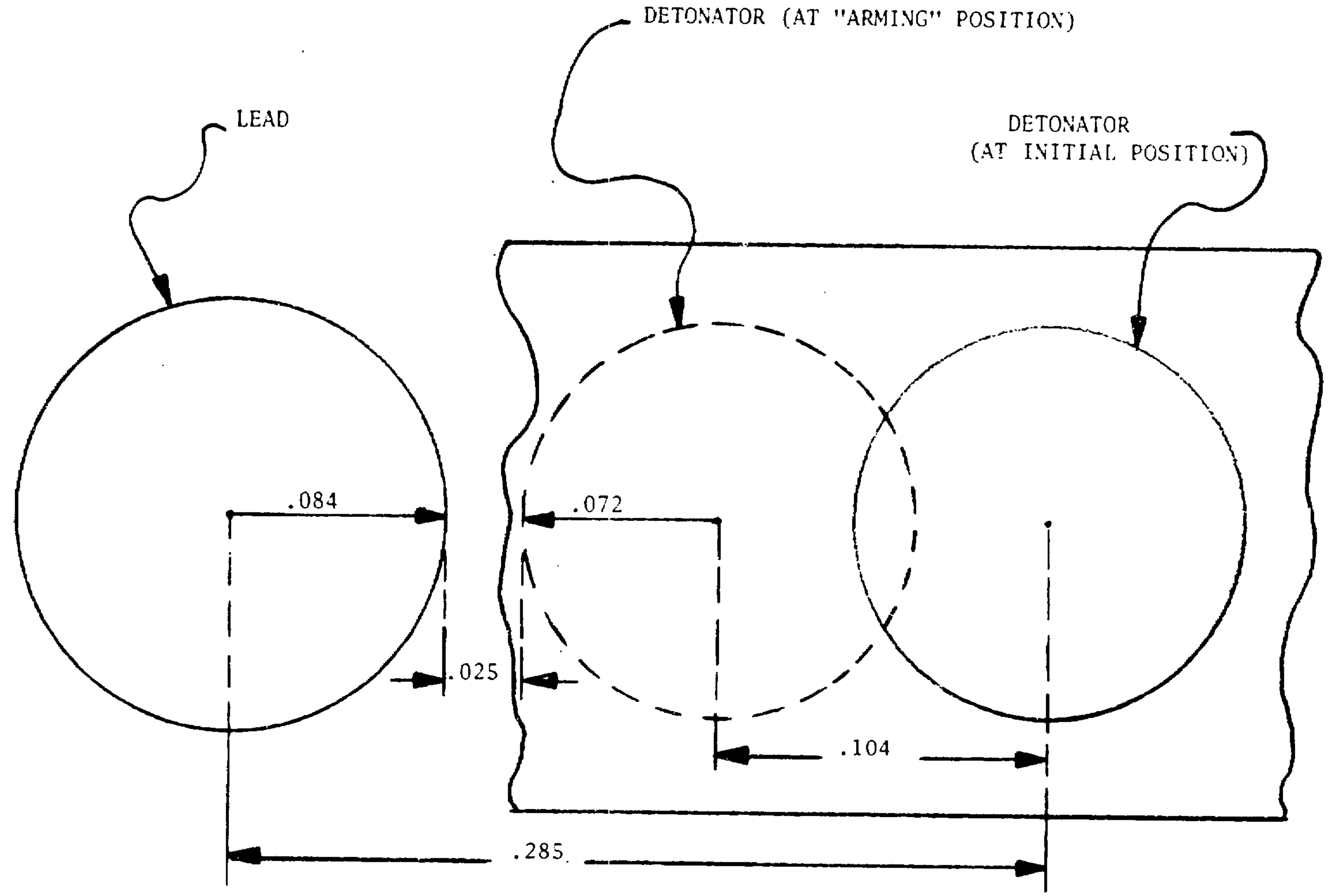
Fig 1 Exploded view of M567 fuze

Table 2

Fuze configuration summary

Fuze features	Fuze model						
	M567	M567*	M567E1	XM935	XM935E1	XM935E2	XM935E3
Inner body							
Pinned			X				X
Not pinned	X	X		X	X	X	
Delay element holder							
Original	X			X	X		
Ribbed		X	X			X	X
Spacer							
Four nibs	X	X		X	X	X	
Six nibs			X				X
Firing pin							
Original	X	X		X	X		
Redesign 1						X	
Redesign 2							
Redesign 3							
Redesign 4							
Redesign 5			X				X
Pull wire							
Short	X			X			
Long		X	X		X	X	X

*Engineering Order (EO) configuration after jolt failure



Note: All dimensions are in inches.

Fig 2 Required slider motion to arm

INVESTIGATION

Component Modifications

The known characteristics of the fuze indicated a weakness in the design of the firing pin. Consequently, several candidate modifications were tested. Table 3 shows the increase in strength of the firing-pin modifications as compared with the original design. The strength increase factor, K, is the ratio of the strength of the particular redesign to the strength of the original.

Table 3

Comparison of firing-pin strength

Design*	Computed nominal failure load (lb)	Strength increase factor (K)
Original	32.8	1
RD #1	96	2.93
RD #2	132	4.02
RD #3	482	14.7
RD #4	410	12.5
RD #5	600	18.3

*RD - redesign

Descriptions of the redesigned firing pins and details of the static analysis of these firing pin designs are covered later in the report.

Tests of another modified component, the ribbed delay element holder, showed an increase in strength of 84%, based on experimental static test fixture values. However, comparison of the performance of fuze components tested in fixtures with those tested in complete assemblies indicates that the sum of the strengths of the separate components is not equivalent to the strength of the fuze when assembled with these elements. The reason for this is that, when in the fuze assembly, all elements do not fail simultaneously. It may thus be concluded that the most realistic method of testing the fuze is to test it as a complete assembly.

Test Results

The details of the jolt, drop, and sequential rough handling tests (summarized in Table 4) are contained in Appendixes B through D. The results of the tests to requirements are summarized in Tables 5 and 6. It may be observed that all fuzes with the long pull wire passed these tests. Included in Table 6 are the results of tests where certain safeties were subverted. The results of these tests are presented for information only, since there is no requirement that the fuze must pass these tests in the configurations shown. The results for the tests to failure are shown in Tables 7 and 8. The fuze functioning rates in the sequential rough handling tests are shown in Table 9.

The sequential rough handling tests referred to in Table 6 require some explanation. Tests of the 192 rounds under "81mm" (Table 6) were conducted in accordance with a TECOM MTP dated April 1970 (MTP 4-2-602). In this plan two rounds from each group of 24 are dropped five times - once in each of five orientations. No other rounds are dropped more than once, as shown in Figure 3. The 60mm rounds were tested in accordance with the coordinated test plan for the LWCM, which requires 50 of each 80-round group to be dropped twice. As shown in Figure 4, of these 50, ten are dropped twice in the same orientation. Of these ten, two are dropped twice horizontally.

By comparison, MIL-STD-331, covering development tests for fuzes, stipulates only one drop per fuze. Hence, fuzes are being subjected to a more rigorous acceptance criterion than that to which they were designed. This is an obvious flaw in the system. It is in the process of being corrected via the Fuze Engineering Group, a tri-service standardization group charged with updating military standards for fuzes.

Less obvious is the difference in severity between the two TECOM procedures shown in Figure 3 and Figure 4. The first indication of a difference came in comparing functioning rates (Table 9) between fuzes subjected to the earlier test sequence (Fig 3) and those subjected to the one shown in Figure 4.

Looking only at the results after bare drop (Table 9), the results show 13 duds in 103 in the 81mm test per Figure 3; 0 duds in 24 in the 60mm test per Figure 3; and 22 duds in 95 in the 60mm tests per Figure 4. A similar difference appears in the overall (average) results. Clearly, the bottom line of the Figure 4 test is more severe. It will be shown later that this test is also more likely to induce safety failures.

Table 4

Summary of safety tests[a]

	M567/XM935	M567E1/XM935E3	Appropriate appendix
Slider static push test	256 lb	926 lb	
Drop test, bare, single drop, ambient	1/6 - 50 feet armed (Others armed when pull wire withdrawn after drop, 15 feet to 50 feet)	0/50 - 100 feet[b]	C
Five-foot repeated drop	2 drops 6/10 3 drops 7/10 5 drops 4/5	0/12 0/12 0/12	C
Jolt test - slider movement without firing pin without pull wire	$\bar{X}$ .0437 SD .0376	.0076 .0026	B
Sequential rough handling (standard test)	1/160	0/160	D
Sequential rough handling subverted safety			H
Firing pin only	5/48	0/160	
Delay holder only	3/48	0/160	
-50°F delay holder only (81mm - double sample)	NOT TESTED	1/180 - armed	

[a] TOTAL NUMBER OF FUZES TESTED - 2,140.
[b] Solid aluminum firing pin; same configuration as new two-piece design.

Table 5

Tests to requirements - jolt, arm, and drop tests

Test	Configuration	Results	
Jolt	Production - short pull wire	2/273	(June 1974)
	Production - long pull wire	0/526	
40-ft drop packaged	Production - long pull wire	11 boxes	0 armed
	81mm pack*	33 rounds	
	60mm pack*	2 boxes	0 armed
		32 fuzes	

* WORST ORIENTATION, with selector cap up

Table 6

Tests to requirements - sequential rough handling

Mortar round		81mm	81mm	81mm	81mm	81mm	60mm
Firing pin	Original	X	-	X	-	X	X
Delay holder	No ribs	-	X	X	-	X	X
	Ribbed	-	-	-	X	-	-
Pull wire	Short	-	-	X	-	-	-
	Long	-	-	-	-	X	X
		5/48	3/48	5/48	0/48	0/192	0/160

Table 7

Tests to failure-bare drop (per test in MIL-STD-331 except height increased)

		Fuze configuration					
Firing pin	Original	X	X				
	One piece aluminum					X	X
Delay holder	No ribs	X	X				
	Ribbed			X	X	X	X
Pull wire	Short						
	Long	X			X		X
Min obs ht		15 feet*	10.3 feet			100 feet	100 feet
50% ht						UNK	
20 feet				0/5			
30 feet				0/5			
40 feet					0/20		
50 feet		1/6					
100 feet						2/22	0/50

*Slider armed after pull wire withdrawn

Table 8

Tests to failure - 60mm bare rounds, repeated drops

		5 feet horizontal			10 feet horizontal	5 feet angles	81mm
Firing pin	Original	X		X		X	X
Delay holder	No ribs	X				X	X
	Ribbed		X	X	X		
Pull wire	Short						
	Long	X		X	X	X	X
DROP NO.	1	0/20					
PRESENT TECOM SRH REQUIREMENT →	2	6/10					
	3	7/10					
	5	4/5	0/5	0/10	0/4	0/10 0/20 0/10	
		STOCKPILE	NOV PDN			PREVIOUS TECOM SHR REQT	

Table 9

Fuze functioning in SRH tests

					Functioning rates[a]			
Fuze	SRH	Ref	No. tested	No. not fired	PD	PD LC	PD LC BD	Avg
M567	48	APG MT-4632 Apr 75	192	3[b]	1.00 (0/23)	0.968 (2/63)	0.874 (13/103)	0.921 (15/189)
XM935	48	APG MT-4536 Oct 74	48	0	0.889 (2/18)	1.00 (0/6)	1.00 (0/24)	0.958 (2/48)
XM935	160	LWCMS DT II	160	10[c]	1.00 (0/33)	0.954 (1/22)	0.768 (22/95)	0.847 (23/150)

[a] Functioning rates are presented as the numbers of fuzes reported to function at impact as a fraction of the numbers tested. *The fractions in parentheses indicate the number of duds* recorded over the number tested. PD = package drop, LC = loose cargo, BD = bare drop, avg = average.

[b] Could not be uploaded for firing.

[c] One premature, *nine not fired*.

As an ongoing test in this program, drop tests of bare rounds with the fuze impacting steel, wood, concrete and sand targets, have been conducted from heights up to 100 feet. These rounds are dropped so that the direction of the target round impact force is in a "worst case" orientation along the slider axis with the selector switch up. Each round is instrumented with an accelerometer along this direction, and these data are presently being reduced.

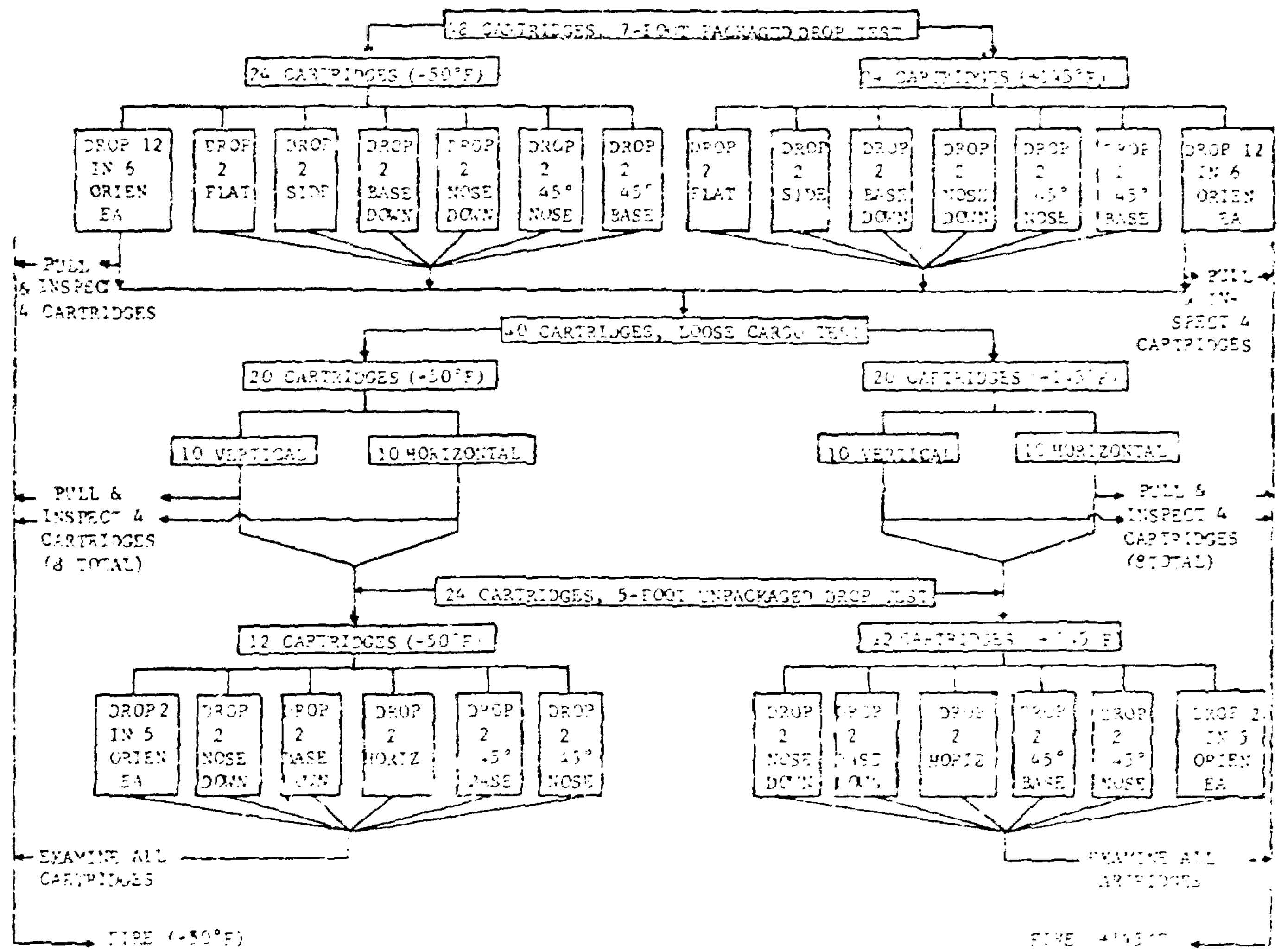


Fig 3 Sequential rough handling test for artillery, mortar, and recoilless rifle ammunition: one or two items per package (complete rounds)

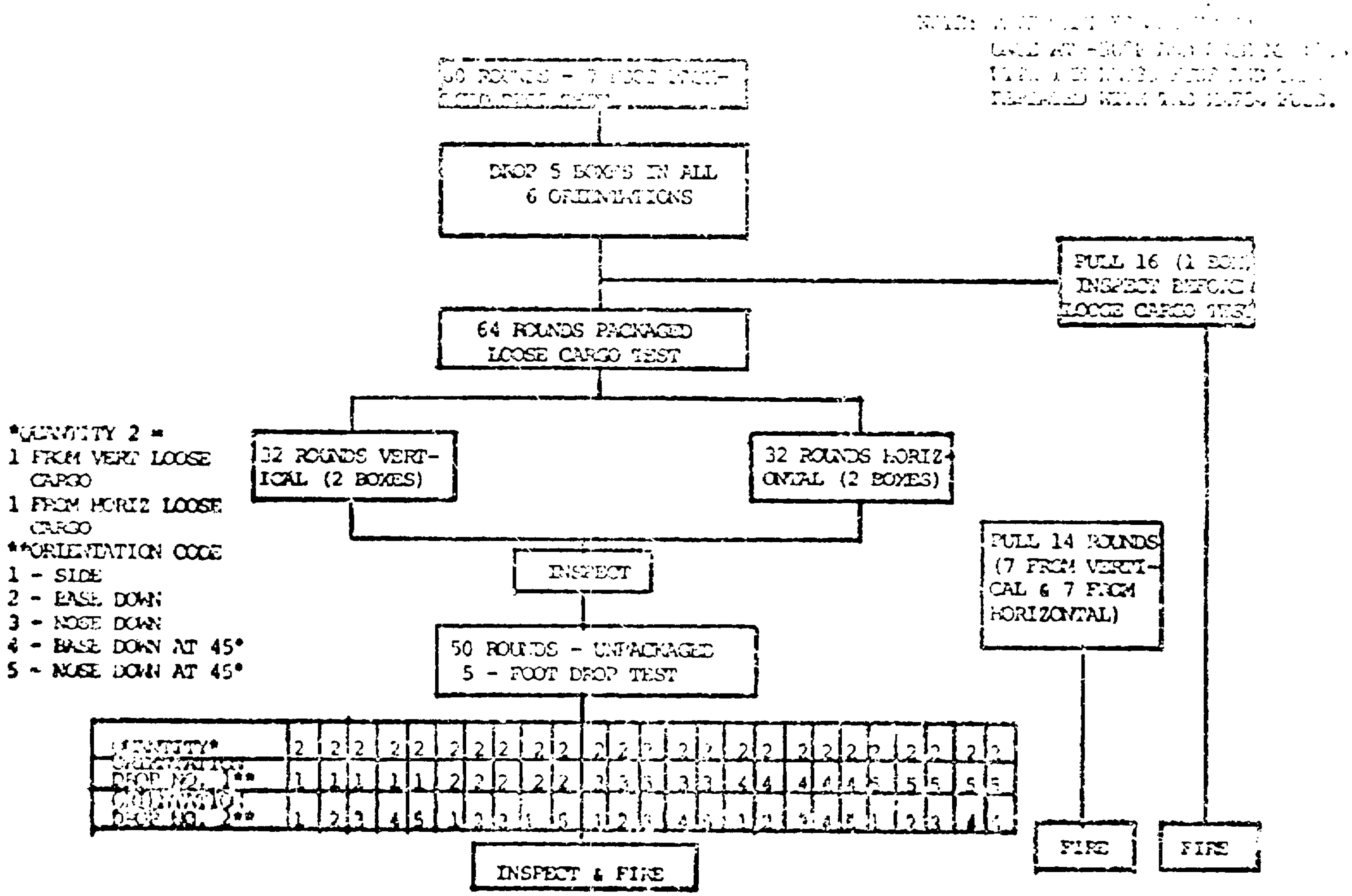


Fig 4 Test plan for LWCM

Static Failure Analysis of Long Pull Wire and Original and Candidate Firing-Pin Designs

Maximum Load Required to Force Slider Past Pull Wire Only (Superquick Position)

In the analysis of the slider and pull-wire interaction, the following assumptions were made:

1. The small gap between the wire and the delay holder is closed under low values of load on slider.

2. The local yielding at the edges where the wire contacts the slider and the delay holder is neglected.

3. The wire bends in a plastic hinge mode at the location where the wire contacts the edge of the delay holder.

4. The coefficient of friction at all sliding surfaces is assumed to be constant.

5. The yield strength of the pull wire material is assumed to be 75% of the tensile strength.

6. Separation of body halves does not occur.

7. The initial elastic strain energy of the pull wire is neglected.

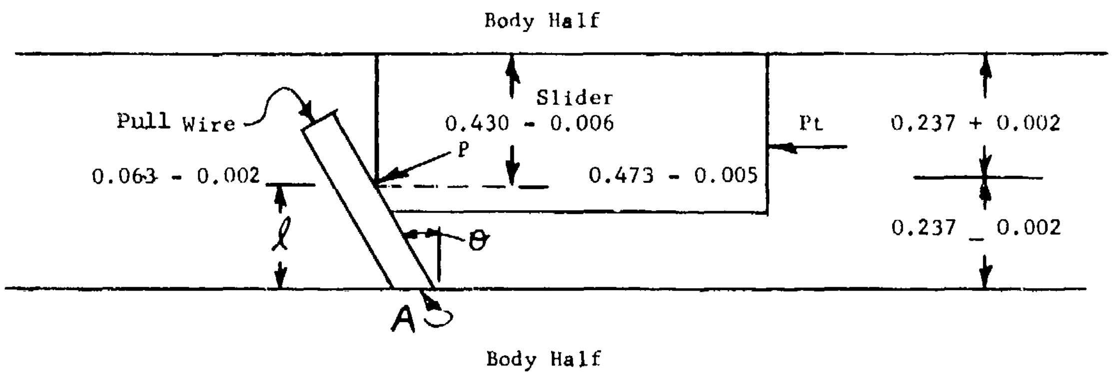


Fig 5 Slider pull wire configuration under static loading condition

Figure 5 shows the slider with the static load, P_t, applied. The maximum value of P_t will occur when a plastic hinge is just formed at Point A. The distribution of stresses in the plastic hinge is shown in Figure 6, where A is the cross section area and

$$r = \frac{d}{2} \tag{1}$$

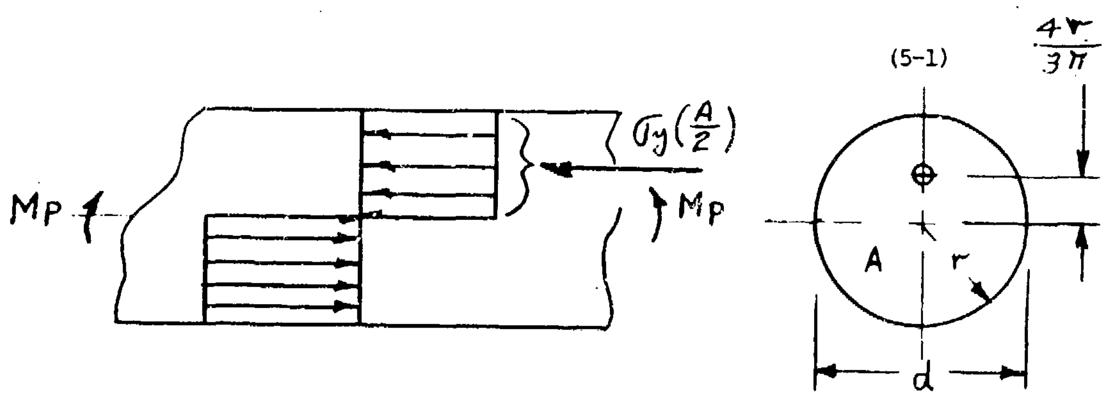


Fig 6 Stress distribution of pull wire under plastic hinge condition

The plastic moment, M_p, is then related to the yield strength, σy, by

$$M_p = 2 \left[\frac{A}{2}\right] \frac{4\gamma}{3\pi} \tag{2}$$

$$A = \frac{\pi d^2}{4} \tag{3}$$

$$M_p = \frac{d^3}{6} \tag{4}$$

Force P is the normal contact force between the edge of the slider and the pull wire. From Figure 5,

$$M_p = P\left[\frac{\ell}{\cos\theta}\right] \tag{5}$$

$$P = \frac{d^3 \cos\theta}{6\,\ell} \tag{6}$$

The static force, P_t, which is applied to the slider must overcome three force effects. These are:

1. The development of force P to form a plastic hinge.

2. Sliding friction between the slider and the pull wire.

3. Sliding friction between the slider and the wall of the slider cavity.

An additional force, which is considered in a subsequent section of the report, is fracture or bending of the tip of the firing pin.

The free-body diagram of the slider is shown in Figure 7. All moment effects are neglected, and force P_t is assumed to be concentrically applied.

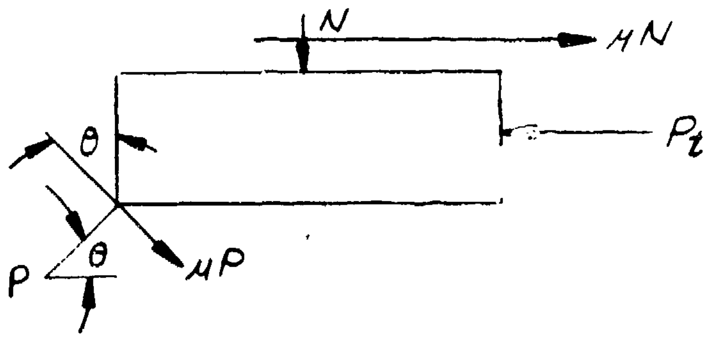


Fig 7 Slider free-body diagram

The force equilibrium requirements are:

$$N + \mu P \cos\theta - P \sin\theta = 0 \tag{7}$$

$$P_t - \mu N - \mu P \sin\theta - P \cos\theta = 0 \tag{8}$$

From which

$$P_t = \left[(1 - \mu^2) \cos\theta + 2\mu \sin\theta\right] P \tag{9}$$

The combination of Equations 4, 5, and 9 results in

$$P_t = \left[(1 - \mu^2) \cos\theta + 2\mu \sin\theta\right] \frac{\sigma y\ d^3 \cos\theta}{6\,\ell} \tag{10}$$

Equation 10 relates the static force, P_t, required to move the slider with σy, the yield strength of the pull-wire material.

The end view of the slider is shown in Figure 8.

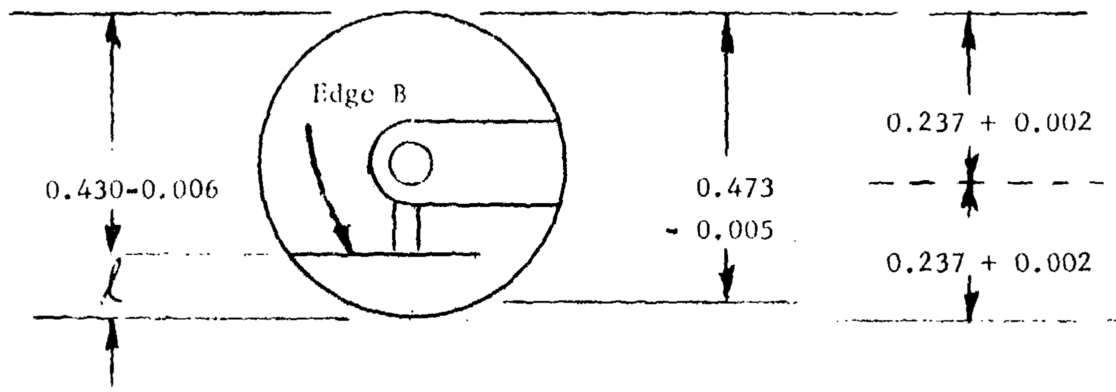


Fig 8 Slider, end view

The dimension ℓ is the same as that shown in Figure 5. The local yielding of Edge B is neglected. In addition, the gap between the pull wire and the delay holder is assumed to be closed during the application of the initial preload, and the local yielding of the edge of the delay holder is neglected.

The pull-wire material is spring steel, Spec ASTMA-227, with the range of ultimate tensile strengths shown in Table 10.

Table 10

Pull-wire material properties

Class I		Class II	
Min	Max	Min	Max
237,000 psi	272,000 psi	273,000 psi	308,000 psi

The numerical value of P_t will now be found for the case of nominal dimensions and material properties, and for the two cases of extreme tolerance accumulation.

Nominal Case

The nominal value of ultimate strength, $\sigma\mu$, is assumed to be the mean of the extreme values in the table above, or

$$\sigma\mu = \frac{237,000 + 308,000}{2} = 272,500 \text{ psi} \tag{11}$$

The yield strength, σy, is then estimated to be equal to 75% of the ultimate strength, so that

$$\sigma y = 0.75\ (272,500) = 204,000 \text{ psi} \tag{12}$$

The remaining nominal values of the problem are

$$d = 0.063 \text{ in.} \tag{13}$$

$$\theta = 270^\circ \tag{14}$$

$$\mu = 0.21 \text{ (zinc die casting on zinc die casting)} \tag{15}$$

$$\ell = 2\ (0.237) - 0.430 = 0.043 \text{ in.} \tag{16}$$

Equation 10 then appears as

$$P_t = \left[(1 - 0.21^2) \cos 27^\circ + 2\ (0.21) \sin 27^\circ\right] \frac{204,000\ (0.063)^3 \cos 27^\circ}{6\ (0.043)} \tag{17}$$

$$P_{t', \text{nom}} = 184 \text{ lb} \tag{18}$$

This would be the maximum value of static load which the slider could support before the onset of plastic bending of the pull wire, for the case of nominal dimensions and material properties.

The calculation of the two extreme values of P_t is shown below. For the case of the maximum value of P_t, the conditions are

$$\sigma y = \text{Maximum} = 0.75\ (308,000) = 231,000 \text{ psi} \tag{19}$$

$$d = \text{Maximum} = 0.063 \text{ in.} \tag{20}$$

$$\ell = \text{Minimum} = 2\ (0.237) - 0.430 = 0.044 \text{ in.} \tag{21}$$

Using Equation 10

$$P_t, \text{max} = \left[(1 - 0.21^2) \cos 27° + 2\ (0.21) \sin 27°\right] \frac{\cos 27°}{6} \left[\frac{231,000\ (0.063)^3}{0.044}\right] \tag{22}$$

$$P_t, \text{Max} = 203 \text{ lb} \tag{23}$$

For the case of the minimum value of P_t, the conditions are

$$\sigma y = \text{Minimum} = 0.75\ (237,000) = 178,000 \text{ psi} \tag{24}$$

$$d = \text{Minimum} = 0.063 - 0.002 = 0.061 \text{ in.} \tag{25}$$

$$\ell = \text{Maximum} = 2\ (0.239) - 0.424 = 0.054 \text{ in.} \tag{26}$$

Equation 10 then yields

$$P_t, \text{min} = \left[(1 - 0.21^2) \cos 27° + 2\ (0.21) \sin 27°\right] \frac{\cos 27°}{6} \left[\frac{178,000\ (0.061)^3}{0.054}\right] \tag{27}$$

$$P_t, \text{Min} = 115 \text{ lb} \tag{28}$$

The range of computed value of P_t is then

$$P_t,\ \text{Min} = 115\ \text{lb} \tag{29}$$

$$P_t,\ \text{Nom} = 184\ \text{lb} \tag{30}$$

$$P_t,\ \text{Max} = 203\ \text{lb} \tag{31}$$

Any local identation between the pull wire and the mating surfaces, or any separation of the body halves, will lower all three of the above numerical values.

Energy Required to Move Slider in From Safe Position to Superquick Position

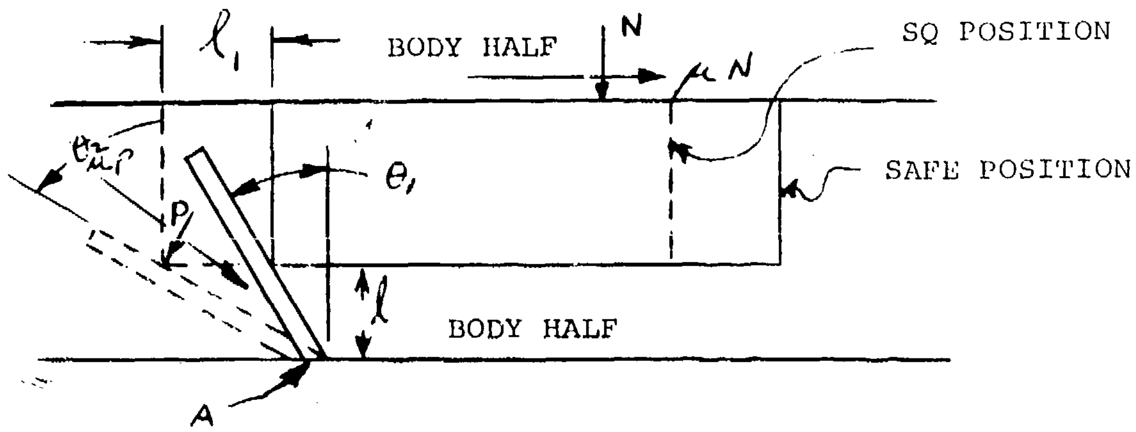


Fig 9 Slider-pull wire configuration

In Figure 9, ℓ_1 is the motion of the slider from the safe position to the superquick position. The energy required to move the slider through this displacement is used to overcome the following effects:

1. Plastic bending of the pull wire about point A.

2. Friction force along the pull wire.

3. Friction force along the upper body half.

4. Indenting of edges in slider and in delay holder.

5. Plastic "gouging" of end plate by arming pin.

The last two effects, as well as the initial elastic strain energy of the wire, are neglected in the first analysis. Since both P and N are functions of θ, an integrated work will be obtained as the slider traverses the distance ℓ_1.

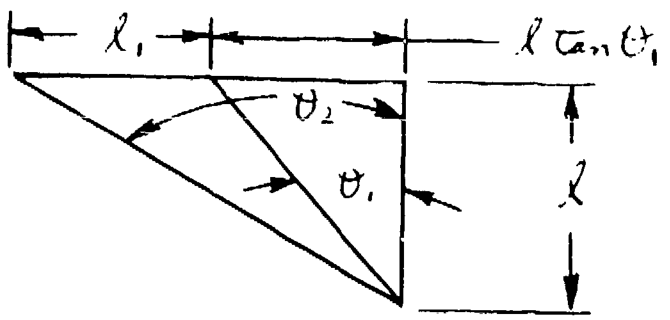


Fig 10

Slider-displacement configuration

θ_1 and θ_2 are the initial and final positions of the pull wire. From Figure 10

$$\theta_2 = \tan^{-1} \left[\frac{\ell \tan \theta_1 + \ell_1}{\ell} \right] . \tag{32}$$

The work done, W_1, by the plastic moment, M_p, is then

$$W_1 = M_p (\theta_2 - \theta_1) \text{ Work of plastic bending} \tag{33}$$

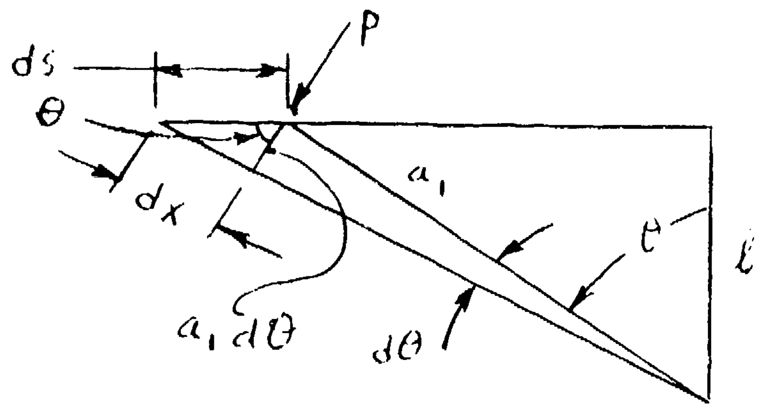


Fig 11 Slider force-displacement diagram

The work done, W_2, by the friction forces between the pull wire and the slider, following Figure 11, is

$$W_2 = \int_{\theta_1}^{\theta} \mu p dx \tag{34}$$

Using

$$a_1 + \frac{\ell}{\cos \theta} \tag{35}$$

$$dx = (a_1 d\theta) \tan \theta \tag{36}$$

$$P = \frac{M_P \cos \theta}{\ell} \tag{37}$$

Where M_P is given by Equation 5

$$W_2 = \int_{\theta_1}^{\theta_2} \mu \left[\frac{M_P \cos \theta}{\ell} \right] \frac{\ell}{\cos \theta} \tan \theta d\theta \tag{38}$$

$$W_2 = \mu M_p \int_{\theta_1}^{\theta_2} \tan\theta d\theta \tag{39}$$

$$W_2 = -\mu M_p \left[\ell N \cos\theta\right] \Big|_{\theta_1}^{\theta_2} \tag{40}$$

The work done, W_3, by the friction forces along the upper body half, is

$$W = \int_{\theta_1}^{\theta_2} \mu N ds \tag{41}$$

With $$dS = \frac{a_1 d_\theta}{\cos\theta} = \frac{\ell d_\theta}{\cos^2\theta} \tag{42}$$

And, following Equation 7,

$$N = P \sin\theta - P\mu\cos\theta \tag{43}$$

W_3 appears as

$$W_3 = \mu \int_{\theta_1}^{\theta_2} P(\sin\theta - \mu\cos\theta) \frac{\ell d\theta}{\cos^2\theta} \tag{44}$$

Replacing P by its equivalent from Equation 5,

$$W_3 = \mu \int_{\theta_1}^{\theta_2} \frac{Mp \cos\theta}{\ell} (\sin\theta - \mu\cos\theta) \frac{\ell d\theta}{\cos^2\theta} \tag{45}$$

$$W_3 = \mu Mp \int_{\theta_1}^{\theta_2} (\tan\theta - \mu) d\theta \tag{46}$$

The work of friction forces on upper body half is given by:

$$W_3 = \mu Mp \left\{ [-\ln \cos \theta] \Big|_{\theta_1}^{\theta_2} - \mu (\theta_2 - \theta_1) \right\} \tag{47}$$

Numerical results will now be obtained for the case of nominal dimensions and material properties. These nominal values are:

$$\sigma y = 204,000 \text{ psi} \tag{48}$$

$$\ell = 0.043 \text{ in.} \tag{49}$$

$$d = 0.063 \text{ in.} \tag{50}$$

$$\theta_1 = 27^\circ \tag{51}$$

$$\ell_1 = 0.286 \text{ in.} \tag{52}$$

$$\theta_2 = \tan^{-1} \left[\frac{0.043 \tan 27^\circ + 0.286}{0.043} \right] \tag{53}$$

$$\theta_2 = 82^\circ \tag{54}$$

Using Equation 4,

$$M_p = \frac{\sigma y \ d^3}{6} = \frac{204,000 \ (0.063)^3}{6} = 8.54 \text{ in.-lb} \tag{55}$$

And with Equation 33,

$$W_1 = 8.54 \ (82-27) \frac{\pi}{180} = 8.18 \text{ in.-lb} \tag{56}$$

Using $\mu = 0.21$ for zinc die casting on zinc die casting, Equation 40 appears as

$$W_2 = -0.21 \ (8.54) \left[\ln \cos 82^\circ - \ln \cos 27^\circ \right] \tag{57}$$

$$W_2 = 3.31 \text{ in.-lb} \tag{58}$$

And Equation 47 is

$$W_3 = 0.21\ (8.54) \left\{ -\ln \cos 82^\circ + \ln \cos 27^\circ - 0.21\ (82 - 27) \frac{\pi}{180} \right\} \tag{59}$$

The total energy, W_T, is then

$$W_T = 8.18 + 3.31 + 2.95 = 14.4 \text{ in.-lb} \tag{60}$$

The distribution of this energy is

$$\text{Bending of pull wire} - \frac{818}{14.4} = 58.4\% \tag{61}$$

$$\text{Friction of pull wire} - \frac{3.31}{14.4} = 23.0\% \tag{62}$$

$$\text{Friction of body half} - \frac{2.95}{14.4} = 20.5\% \tag{63}$$

The extreme values of energy, using the maximum and minimum dimensions and material properties given earlier in this section, are

$$W_T,\ \text{Min} = 11.4 \text{ in.-lb} \tag{64}$$

$$W_T,\ \text{Max} = 16.3 \text{ in.-lb} \tag{65}$$

Static Load - Displacement Function for Motion of Slider in Slider Cavity

The total displacement of the slider in the guide from the safe position to the superquick position and following Figure 10, is ℓ_1. From Figure 11, and defining

$$\ell_1 = \int_0^{\ell_1} ds \tag{66}$$

An expression will now be obtained in the form

$$P_T = P_T(S) \tag{67}$$

From Equation 42

$$dS = \frac{\ell d\theta}{\cos^2\theta} \tag{68}$$

And

$$\int_0^S dS = \int_{\theta_1}^{\theta} \frac{\ell d\theta}{\cos^2\theta} \tag{69}$$

In Equation 69, both S and θ are variable upper limits. This equation is integrated to obtain

$$S = \ell \tan\theta \Big|_{\theta_1}^{\theta} = \ell (\tan\theta - \tan\theta_1) \tag{70}$$

$$\tan\theta = \frac{S}{\ell} + \tan\theta_1 \tag{71}$$

Equation 71 is shown graphically in Figure 12, from which

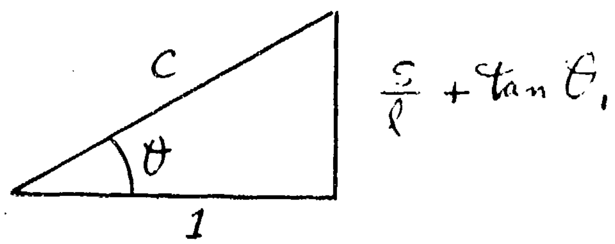


Fig 12 Graphic representation of equation 71

$$C^2 = \frac{S^2}{\ell^2} + 2\left(\frac{S}{\ell}\right)\tan\theta_1 + \tan^2\theta_1 \tag{72}$$

Eliminating P between Equations 5 and 9 results in

$$P_T = [\ (1 - \mu^2)\ \cos \theta + 2\mu \sin \theta]\ \frac{M_P \cos \theta}{\ell} \tag{73}$$

From Figure 12

$$\sin \theta = \frac{\frac{S}{\ell} + \tan \theta_1}{C} \tag{74}$$

$$\cos \theta = \frac{1}{C} \tag{75}$$

$\theta = \theta(S)$ is now eliminated from Equation 73, using Equations 73 and 75 with the final result

$$P_T = \frac{\frac{M_P}{\ell} \left[(1 - \mu^2) + 2\mu \left(\frac{S}{\ell} + \tan \theta'\right) \right]}{\frac{S^2}{\ell^2} + 2 \left(\frac{S}{\ell}\right) \tan \theta_1 + \tan^2 \theta_1} \tag{76}$$

In Equation 75

$$0 \leq S \leq \ell_1 \tag{77}$$

Using the nominal dimensions and material properties presented earlier,

$$P_T = \frac{1940S + 233}{541\ S^2 + 23.75 + 1.26} \tag{78}$$

Where P_T is in pounds, and S is in inches

For S = 0, P_T is maximum, with the valve

$$P_T = 184 \text{ lb} \tag{79}$$

which agrees with the answer obtained earlier. The nominal maximum valve of ℓ_1 is 0.104 in. with the corresponding minimum value of P_T of

$$P_T = 45.4 \text{ lb} \tag{80}$$

Equation 78 is plotted in Figure 13.

Stress Analysis of Firing Pin Designs

In analyzing the strengths of the several firing pin designs:

1. The failure mode is assumed as indicated, and this assumption is confirmed by examination of the test specimens.

2. The firing pin end behaves as a cantilever beam with a concentrated lateral force acting on it.

3. For the steel firing pin ends, the yield strength is estimated as 75% of the tensile strength.

Figure 14 shows the orientation of the firing pin with respect to the slider edge. The range of values of X is

$$X_{max} = 0.177 - 0.0311 = 0.146 \text{ in.} \tag{81}$$

$$X_{min} = 0.162 - 0.0711 = 0.091 \text{ in.} \tag{82}$$

$$X_{nom} = \frac{0.146 + 0.091}{2} = 0.119 \text{ in.} \tag{83}$$

Nominal Case

The diameter at the base of the frustrum of the cone is d and d_1 is the diameter under the load.

$$d = 0.015 + 2\ (0.170)\ \tan 13° = 0.093 \text{ in.} \tag{84}$$

$$X_{nom} = 0.119 \text{ in.} \tag{85}$$

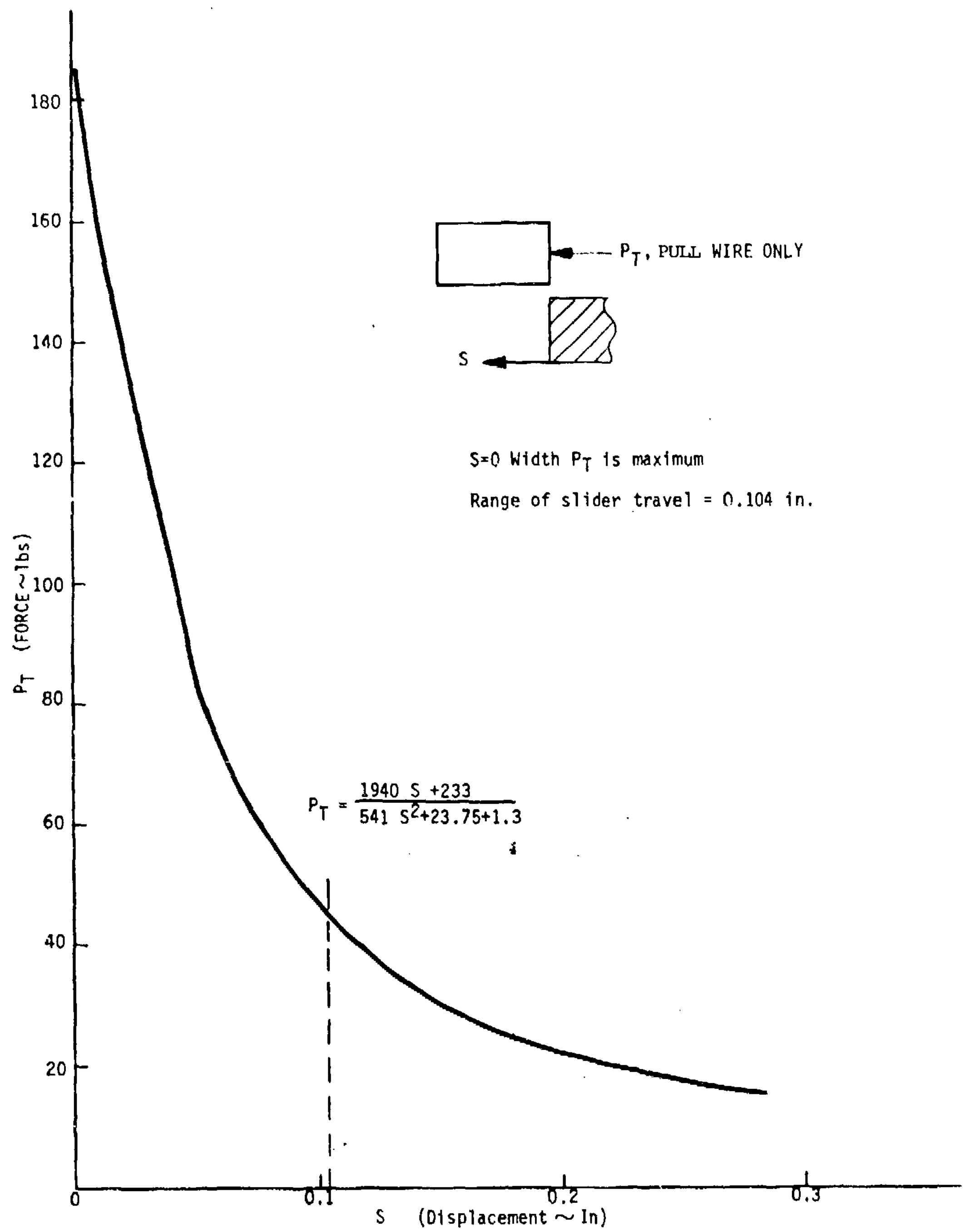


Fig 13 Static force-displacement curve for slider with pull wire only

Original Firing Pin with Conical Aluminum Tip
(Dwg No. 924629 Rev A)

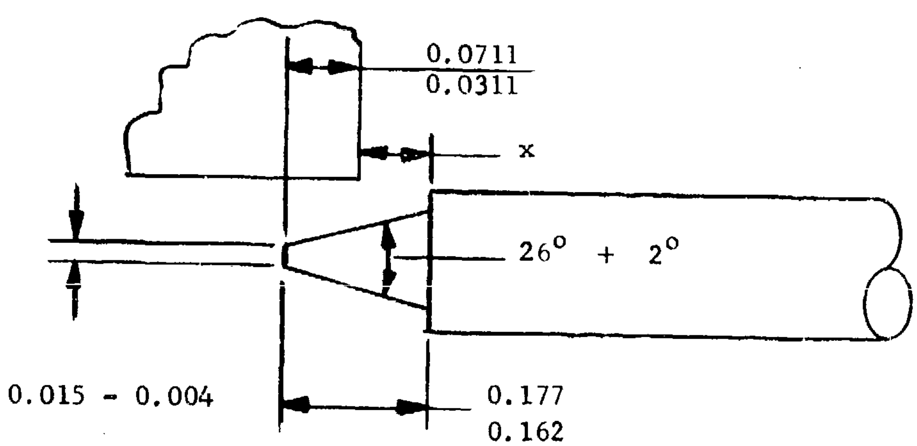


Fig 14 Firing pin, original design

For 7075 - T651 aluminum,

$$\text{Ultimate strenth} = 83{,}000 \text{ psi} \tag{86}$$

$$\text{Yield strength} = 73{,}000 \text{ psi} \tag{87}$$

$$\text{Ultimate shear strength} = 48{,}000 \text{ psi} \tag{88}$$

For bending,

$$\sigma = \frac{Mc}{I} = \frac{M\,(\frac{d}{2})}{\frac{\pi\, d^4}{64}} = \frac{32\; M}{\pi\, d^3} \tag{89}$$

Using yielding as the criterion,

$$73{,}000 = \frac{32\;(0.119\;P)}{\pi\;(0.093)^3} \quad \text{or } P = 48.4 \tag{90}$$

For development of a full plastic hinge at the base,

$$P\ell = \frac{\sigma y\; d^3}{6} \tag{91}$$

$$P = \frac{73{,}000\;(0.093)^3}{6\;(0.119)} = 82.2 \text{ lb} \tag{92}$$

For direct shear under the load,

$$d_1 = 0.015 + 2\;(0.170 - 0.119)\;\tan 13^\circ \tag{93}$$

$$d_1 = 0.039 \tag{94}$$

$$\tau = \frac{P}{A} \tag{95}$$

$$48{,}000 = \frac{P}{\frac{\pi\;(0.039)^2}{4}} \tag{96}$$

$$P = 56 \text{ lb} \tag{97}$$

The conclusion is that shear failure governs. This was later confirmed by examination of the test specimens.

Condition for P max

$$d_1\text{, max} = 0.015 + 2\ (0.162 - 0.091)\ \tan 14° \quad (98)$$

$$d_1\text{, max} = 0.050 \text{ in.} \quad (99)$$

$$48{,}000 = \frac{\text{P Max}}{\frac{\pi\ (0.050)^2}{4}} \quad (100)$$

$$\text{P Max} = 95.8 \text{ lb} \quad (101)$$

Condition for P min

$$d_1\text{, min} = 0.011 + 2\ (0.177 - 0.146)\ \tan 13° \quad (102)$$

$$d_1\text{,} = 0.025 \text{ in.} \quad (103)$$

$$48{,}000 = \frac{\text{P min}}{\frac{(0.025)^2}{4}} \quad (104)$$

$$\text{P min} = 24.1 \text{ lb} \quad (105)$$

Summary

$$\text{P min} = 24.1 \text{ lb} \quad (106)$$

$$\text{P nom} = 56 \text{ lb} \quad (107)$$

$$\text{P max} = 95.8 \text{ lb} \quad (108)$$

$$\text{P exp, avg} = 32.8 \text{ (Test A - fixture only)} \quad (109)$$

The above results do not consider any variations in the material strengths.

Redesign (RD) No. 1, Cylindrical Aluminum Shank,
Small Radius = 0.020 (Dwg 9299428 Rev C)

The dimensions are shown in Figure 15. Reference A is the nose end of the body halves, and Reference B is the edge of the slider.

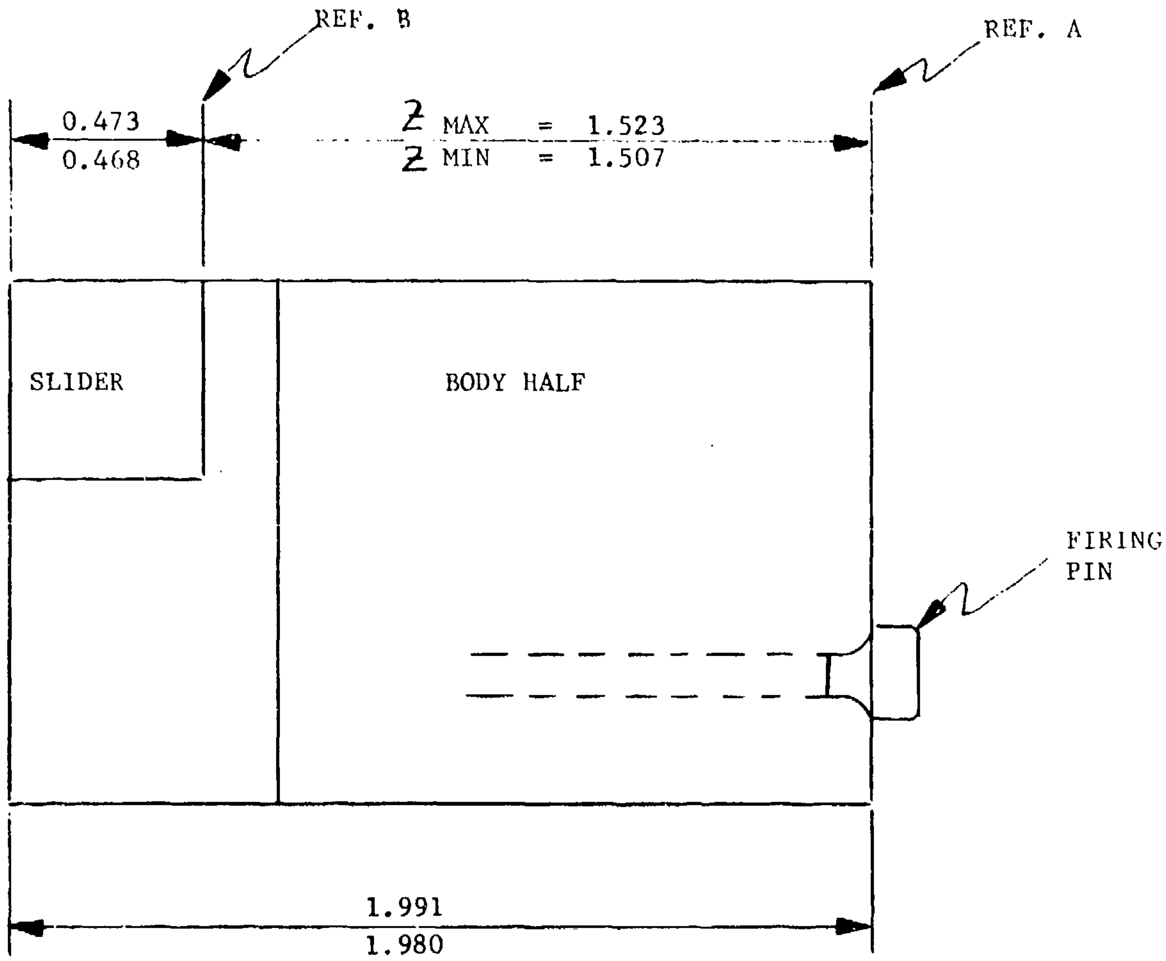


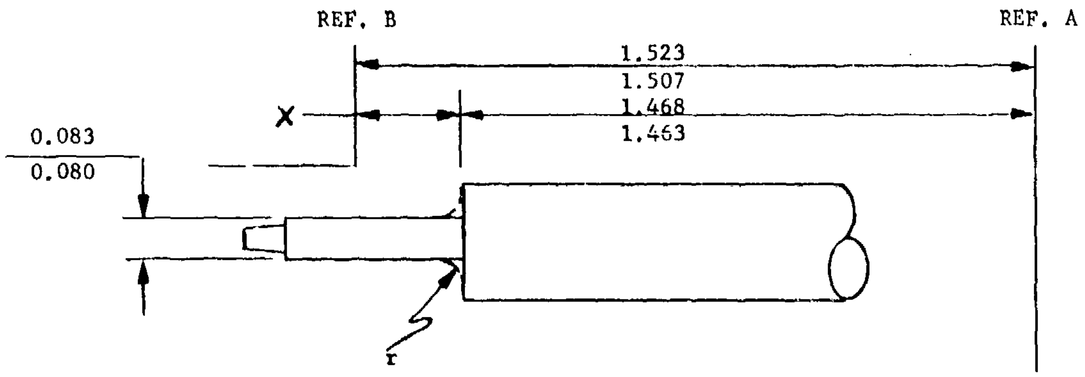
Fig 15 Inner body and slider configuration

From Figure 15,

$$Z\ max = 1.991 - 0.468 = 1.523 \text{ in.} \tag{110}$$

$$Z\ min = 1.980 - 0.473 = 1.507 \text{ in.} \tag{111}$$

Figure 16 shows the configuration for Redesign No. 1.



DRAWING XM720-002 (Dimension 1.493 - 0.005 changed to 1.468 - 0.005

Fig 16 Firing pin, redesign No. 1

From the figures,

$$X_{max} = 1.523 - 1.463 = 0.060 \text{ in.} \tag{112}$$

$$X_{min} = 1.507 - 1.468 = 0.039 \text{ in.} \tag{113}$$

For RD No. 1, the above values are reduced by 0.020 to reflect the effect of the fillet radius. Thus,

$$X_{max}\ 31 = 0.060 - 0.020 = 0.040 \text{ in.} \tag{114}$$

$$X_{min}\ \#1 = 0.039 - 0.020 = 0.019 \text{ in.} \tag{115}$$

The examination of the test specimens revealed an initial cracking at the outer fibers, followed by material failure of an inner core of the material. It will thus be assumed the failure in this case is not a

plastic hinge, but rather a failure where the computed stresses in the outer fibers are somewhere between the yield and the ultimate strengths of the material, 7075 - T651 aluminum. In all cases, the nominal load is taken to be the arithmetic mean of the maximum and minimum values. Using -

$$\sigma = \frac{32\ M}{\pi\ d^3} \tag{116}$$

$$M = Px \tag{117}$$

$$P = \frac{\sigma\ \pi\ d^3}{32\ x} \tag{118}$$

$$P\ \text{max, yield} = \frac{73,000\ \pi\ (0.083)^3}{32\ (0.019)} = 215\ \text{lb} \tag{119}$$

$$P\ \text{max, ult} = \frac{83,000\ (215}{73,000} = 245\ \text{lb} \tag{120}$$

For P min,

$$d\ \text{min} = 0.080\ \text{in.} \tag{121}$$

$$P\ \text{min, yield} = \frac{73,000\ \pi\ (0.080)^3}{32\ (0.040)} = 91.5\ \text{lb} \tag{122}$$

$$P\ \text{min, ult} = \frac{83,000}{73,000}\ (91.5) = 104\ \text{lb} \tag{123}$$

The nominal values are

$$P\ \text{nom, yield} = 153\ \text{lb} \tag{124}$$

$$P\ \text{nom, ult} = 175\ \text{lb} \tag{125}$$

These results are summarized in Table 11.

Table 11

Firing pin, redesign No. 1, failure loads range

	Yield (lb)	Ultimate (lb)
P min	91.5	104
P nom	153	175
P max	215	245

Comparison is then made with the two experimental values

P = 96 lb - test fixture - Test D (126)

P = 113 lb - fuze - Test F (127)

Redesign (RD) No. 2, Cylindrical Aluminum Shank, Large Radius = 0.030 (Dwg 9299428 Rev D)

The firing pin dimensions are as shown in Figure 16. The effective values of X are

$$X \max = 0.060 - 0.030 = 0.030 \text{ in.} \tag{128}$$

$$X \min = 0.039 - 0.030 = 0.009 \text{ in.} \tag{129}$$

Using $P = \dfrac{\sigma \pi d^3}{32 X}$,

and the material properties of RD No. 1,

$$P \max,\ \text{yield} = \frac{73{,}000\ \pi\ (0.083)^3}{32\ (0.009)} = 399 \text{ lb} \tag{130}$$

$$P \max \text{ ult} = \frac{83{,}000}{73{,}000}\ (399) = 454 \text{ lb} \tag{131}$$

For P min,

$$d \min = 0.080 \text{ in.} \tag{132}$$

$$P \min,\ \text{yield} = \frac{73{,}000\ \pi\ (0.080)^3}{32\ (0.030)} = 107 \text{ lb} \tag{133}$$

$$P \min,\ \text{ult} = \frac{83{,}000}{73{,}000}\ (107) = 122 \text{ lb} \tag{134}$$

The nominal values are

$$P \text{ nom},\ \text{yield} = 253 \text{ lb} \tag{135}$$

$$P \text{ nom},\ \text{ult} = 288 \text{ lb} \tag{136}$$

The results are summarized in Table 12.

Table 12

Firing pin, redesign No. 2, failure load range

	Yield (lb)	Ultimate (lb)
P min	107	122
P nom	253	288
P max	399	454

Comparison is made with the experimental value

$$P = 132 \text{ lb - fuze - Test J} \tag{137}$$

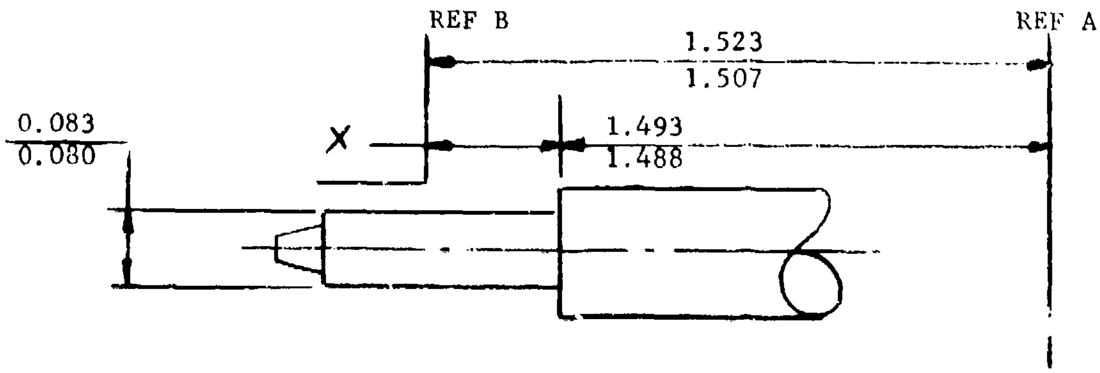
Redesign (RD) No. 3, Threaded Steel Firing-Pin Insert (Dwg XM720-029-3)

Figure 17 shows the configuration for RD No. 3. The moment arms are

$$X\ max = 1.523 - 1.488 = 0.035 \text{ in.} \tag{138}$$

$$X\ min = 1.507 - 1.493 = 0.014 \text{ in.} \tag{139}$$

For Spec ASTMA227 steel, the range of ultimate tensile strength is 227,000 psi to 296,000 psi.



(Dwg No. XM720-028)

Fig 17 Firing pin, redesign No. 3

The yield strength is estimated to be 75% of the ultimate strength, so that

$$\sigma y,\ max = 222,000\ psi \tag{140}$$

$$\sigma y,\ nom = 196,000\ psi \tag{141}$$

$$\sigma y,\ min = 170,000\ psi \tag{142}$$

The mode of failure is assumed to be the development of a full plastic hinge, and this is confirmed by examination of the test specimens. For plastic hinge failure,

$$M = PX = \frac{\sigma y\ d^3}{6} \tag{143}$$

$$P = \frac{\sigma y\ d^3}{6\ell} \tag{144}$$

$$P\ max = \frac{222,000\ (0.083)^3}{6\ (0.014)} = 1511\ lb \tag{145}$$

$$P\ nom = \frac{196,000\ (0.083)^3}{6\ (0.0245)} = 762\ lb \tag{146}$$

$$P\ min = \frac{170,000\ (0.080)^3}{6\ (0.035)} = 414\ lb \tag{147}$$

Comparison is made with the experimental value

$$P = 482\ lb - fuze - Test\ K \tag{148}$$

Redesign (RD) No. 4, Magnaformed Steel Firing-Pin Insert (Dwg XM720-031-3)

For this case, the dimensions are the same as those shown in Figure 17. The loads are then

$$P\ max = 1511\ lb \tag{149}$$

$$P\ nom = 762\ lb \tag{150}$$

$$P\ min = 414\ lb \tag{151}$$

And comparison is made with the experimental value

$$P = 410\ lb - fuze - Test\ O \tag{152}$$

Redesign (RD) No. 5, Flanged Steel Tip (Dwg XM720-036)
Drawing 9299424 and 9299423.

The configuration is shown in Figure 18.

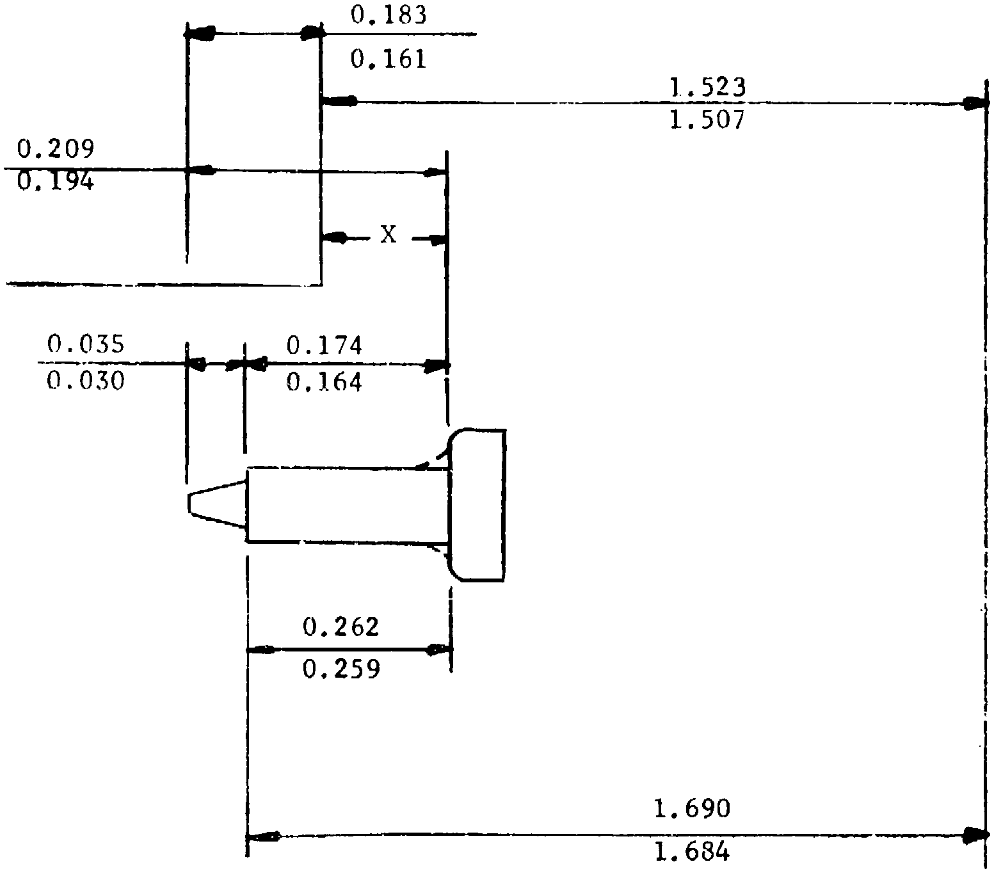


Fig 18 Firing pin, redesign No. 5

The moment arms are

$$X \max = 0.209 - 0.161 = 0.048 \text{ in.} \tag{153}$$

$$X \min = 0.194 - 0.183 = 0.011 \text{ in.} \tag{154}$$

Plastic hinge failure is assumed, and the effect of the fillet radius is neglected. The pin is made of the same material as RD No. 3 and No. 4.

$$P \max = \frac{222{,}000\ (0.083)^3}{6\ (0.011)} = 1923 \text{ lb} \tag{155}$$

$$P \text{ nom} = \frac{196,000\ (0.083)^3}{6\ (0.0295)} = 567 \text{ lb} \tag{156}$$

$$P \text{ min} = \frac{170,000\ (0.080)^3}{6\ (0.048)} = 302 \text{ lb} \tag{157}$$

Comparison is made with the experimental value

$$P = 600 \text{ lb (fuze, Test M)} \tag{158}$$

Stress Analysis of Proposed Zinc-Head Firing Pin (Dwg SK-9575)

The proposed die-cast zinc head is shown in Figure 19. The three failure modes which are analyzed here, are

1. Direct-bearing failure of annular Area A.

2. Direct shear of Area B.

3. Failure as a simple supported plate assembly. The material is zinc die-casting alloy AG 40 A, with the strengths:

Tensile strength = 41,000 psi
Compressive strength = 60,000 psi
Shear strength = 31,000 psi

Bearing Failure

$$A_{Brg} = \frac{\pi}{4} \left[0.144^2 - 0.080^2\right] = 0.011 \text{ in}^2, \tag{159}$$

Using σ Brg = 60,000 psi

$$P \text{ max} = 60,000\ (0.011) - 660 \text{ lb} \quad (160$$

Shear Failure

$$A_{Shear} = \pi\ (0.144)\ 0.085 = 0.038 \text{ in}^2 \tag{161}$$

Using τ = 31,000 psi

$$P \text{ max} = 31,000\ (0.038) = 1192 \text{ lb} \tag{162}$$

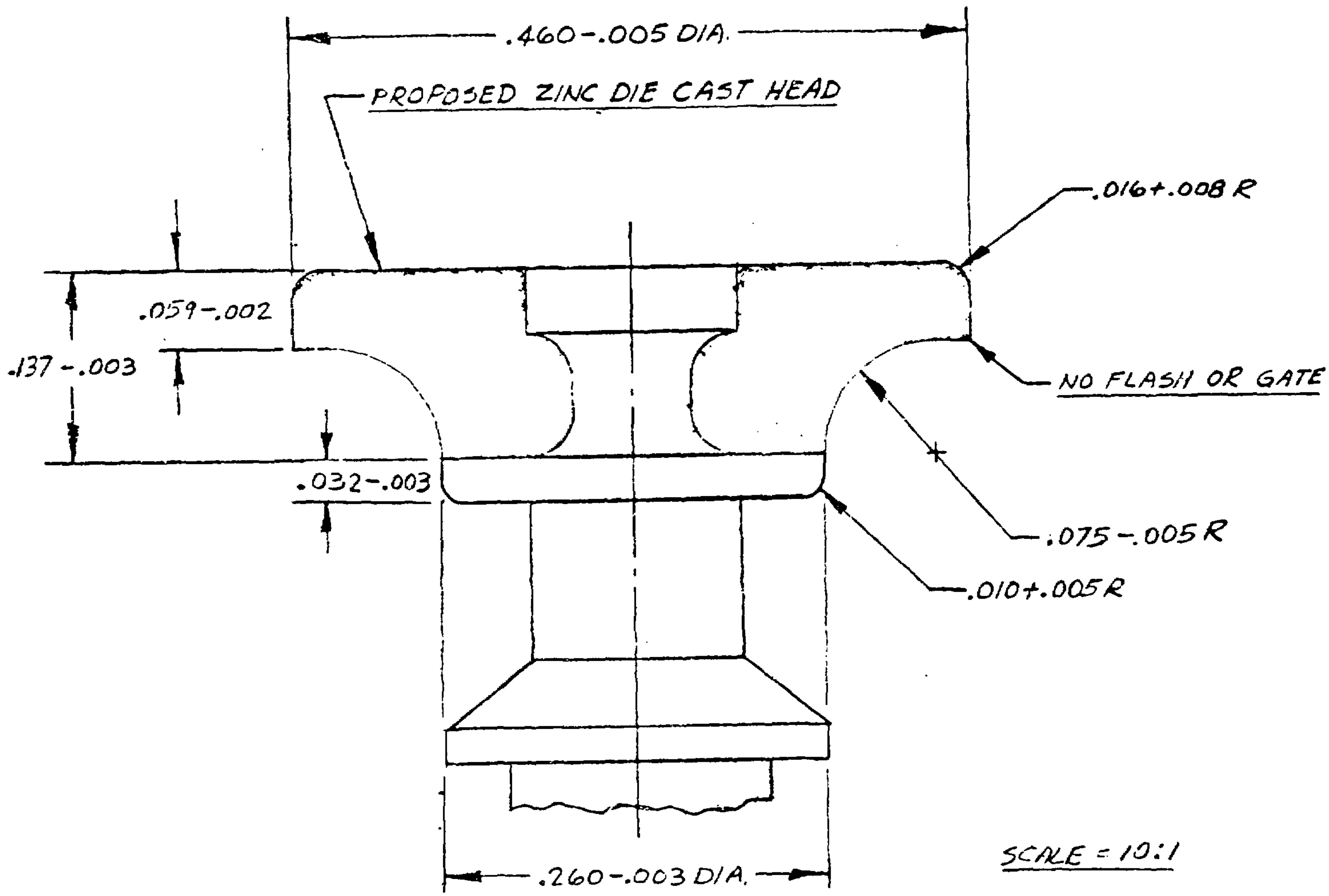


Fig 19 Modified firing pin No. 9246269

Plate Failure Model

The head will now be modeled as a simply supported circular plate with a stiffening ring with an uniformly distributed edge load. Figure 20 shows the assembly. The worst-case condition, where the plate is supported at the outer edge, is assumed.

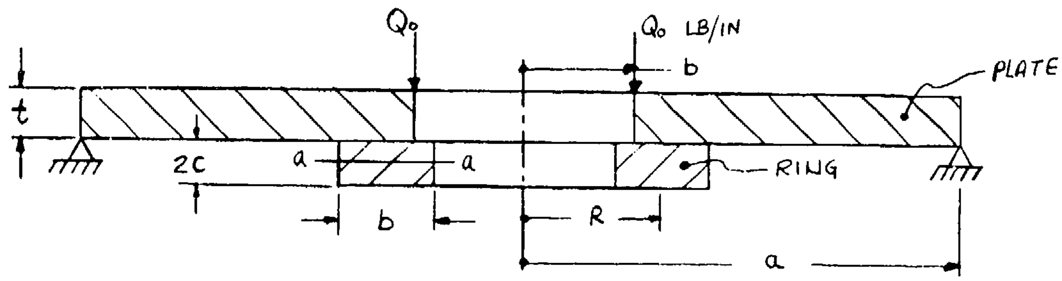


Fig 20 Firing-pin head configuration

The problem will now be solved by superposing the following three cases.

Case 1 - Plate with Uniformly Distributed Edge Load, Qo, in lb/in.

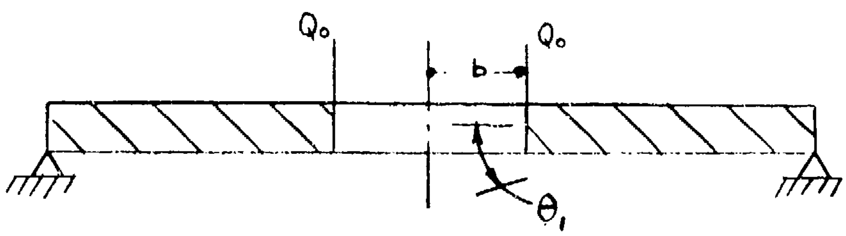


Fig 21 Firing-pin head edge loading

Case 2 - Plate with Uniformly Distributed Edge Mount, Mo, in lb/in.

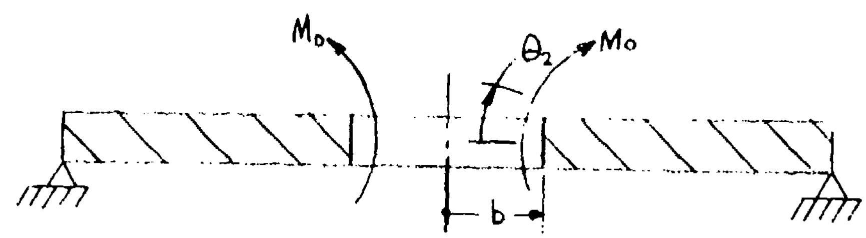


Fig 22 Firing-pin head edge moment loading

Mo is due to internal reaction force of the ring on the plate.

Case 3 - Ring with Uniformly Distributed Edge Moment, Mo, in lb/in.

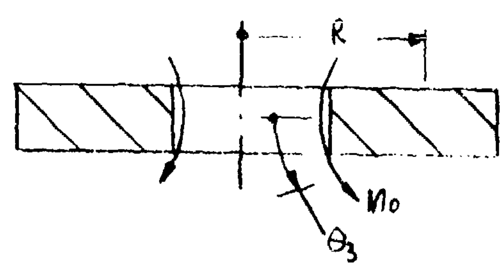


Fig 23 Firing-pin ring edge moment loading

R is the mean radius of the ring.

The condition of compatibility is continuity of slope at the inner edge, or

$$|\theta_1| - |\theta_2| = |\theta_3| \tag{163}$$

From this equation, the value of Mo may be found.

The stresses and slopes for the three cases are shown below, with both their functional and numerical forms.

<u>Case 1</u>

$$Q_0\, 2\,\pi\, b = P \tag{164}$$

$$\theta_1 = \left.\frac{dw}{dr}\right|_{r=b} = \frac{Pb}{8\pi D}\left[2\,\ln\frac{b}{a} - 1 - \frac{(1-\nu)}{(1+\nu)}\right.$$
$$\left. + \frac{2b^2}{a^2-b^2}\left[1 + \frac{a^2}{b^2}\;\frac{(1+\nu)}{(1-\nu)}\right]\ln\frac{b}{a}\right] \tag{165}$$

$$\theta_1 = \frac{P\,(0.072)}{8\pi D}\left[2\;\ln\frac{0.072}{0.230} - 1 - \frac{(1-0.3)}{(1+0.3)}\right.$$
$$\left. + \frac{2\;(0.072)^2}{0.230^2-0.072^2}\left[1 + \frac{0.230^2}{0.072^2}\;\frac{(1+0.3)}{(1-0.3)}\right]\ln\frac{0.072}{0.230}\right] \tag{166}$$

$$\theta_1 = 0.0254\,\frac{P}{D} \tag{167}$$

The maximum normal stress is the tangential bending stress, σ_t, at the inner edge where $r = b$, or

$$\left.\sigma_t\right|_{r=b} = \frac{-3P}{2\pi m t^2}\left[\frac{2a^2\;(m+1)}{a^2-b^2}\;\ln\frac{a}{b} + (m-1)\right] \tag{168}$$

where

$$m = \frac{1}{\nu} \tag{169}$$

$$\left.\sigma_t\right|_{r=b} = -\;\frac{3P}{2\pi\;(3.33)\;(0.059)^2}\left[\frac{2\;(0.230)^2\;4.33}{0.230^2-0.072^2}\;\ln\frac{0.230}{0.072} + \right.$$
$$\left. 2.33\right] \tag{170}$$

$$\sigma_t \Big|_{r=b} = -553P \qquad (171)$$

The minus sign in Equation 171 indicates compressive stress in the upper fibers of the plate.

Case 2

$$\theta_2 = \frac{dw}{dr}\Big|_{r=b} = \frac{a^2\ b^2 Mo}{D(1-\nu)\ (a^2-b^2)} \left[\frac{1}{b} + \left(\frac{1-\nu}{1+\nu}\right) \frac{b}{a^2}\right] \qquad (172)$$

$$\theta_2 = \frac{0.230^2\ (0.072)^2\ Mo}{(1-0.3)\ (0.230^2-0.072^2)\ D} \left[\frac{1}{0.072} + \frac{(1-0.3)}{(1+0.3)}\ \frac{0.072}{0.230^2}\right] \qquad (173)$$

$$\theta_2 = 0.120\ \frac{Mo}{D} \qquad (174)$$

The radial and tangential bending stresses at the inner circumference $r = b$ are

$$\sigma_r \Big|_{r=b} = -\ \frac{6\ Mo}{t^2} = -1723\ Mo \qquad (175)$$

$$\sigma_t \Big|_{r=b} = \frac{6\ Mo}{t^2} \left[\frac{a^2+b^2}{a^2-b^2}\right] \qquad (176)$$

$$\sigma_t \Big|_{r=b} = \frac{6\ Mo}{0.059^2} \left[\frac{0.230^2+0.072^2}{0.230^2-0.072^2}\right] = 2099\ Mo \qquad (177)$$

Case 3

$$\theta_3 = \frac{Mo\ R^2}{EI} \qquad (178)$$

Where I is the moment of inertia of the cross section with respect to the axis, a-a, shown in Figure 20.

Using

$$D = \frac{E\ t^3}{12\ (1-\nu^2)} \qquad (179)$$

Equation 178 may be written as

$$\theta_3 = \frac{Mo\ R^2\ t^3}{12\ (1_{-\nu^2})\ \mathrm{ID}} \tag{180}$$

$$\theta_3 = \frac{Mo\ (0.085)^2\ (0.059)^3}{12\ (1-0.3^2)\ 3.56 \times 10^{-6} D} = 0.0381 \frac{Mo}{D} \tag{181}$$

The condition of compatibility, Equation 163 is then

$$0.0254\ P - 0.120\ Mo = 0.0381\ Mo \tag{182}$$

It may be observed from the above equation that the value of Mo is independent of the value of the modulus of elasticity. Equation 182 is solved, with the result

$$Mo = 0.161\ P \tag{183}$$

The maximum bending stresses in the ring are tangential normal stresses in the planes of the two annular faces. These values are given by

$$\sigma = \frac{M\ R\ C}{I} \tag{184}$$

$$\sigma = \frac{(0.161P)\ 0.085 \left(\frac{0.078}{2}\right)}{3.56 \times 10^{-6}} = 150\ P \tag{185}$$

The criterion of failure will be taken to be the onset of yielding. The yield strength is estimated as 75% of the tensile strength, so that

$$(0.75)\ \ 41{,}000 = 150\ P \tag{186}$$

$$P = 205\ \mathrm{lb} \tag{187}$$

The maximum radial bending stress at the inner radius of the plate, from Equation 175, is

$$\sigma_r \Big|_{r=b} = -1723\ Mo = -1723\ (0.161P) = 0.75\ (41{,}000) \tag{188}$$

$$\sigma_r \Big|_{r=b} = 111\ \mathrm{lb} \tag{189}$$

The maximum tangential stress at the inner radius of the plate is the sum of Equations 171 and 177, or

$$\sigma_t \Big|_{r=b} = -553P + 2099\ Mo \tag{190}$$

$$= -553P + 2099\ (0.161P) = 0.75\ (41{,}000) \tag{191}$$

$$P = 143\ \text{lb} \tag{192}$$

The minimum load to cause the onset of yielding is thus on the order of 111 pounds for the case of maximum radial bending stress at the inner radius. This result is on the low, conservative side, since the edge support of the plate is assumed to be a worst-case condition of support at the outer edge.

Static Test Data

Description of Tests

The static tests were conducted on individual fuze elements and on the fuze assembly, using the instrom compression tester. The loads were applied on the slider, and the results of the tests are one force-displacement curves of slider motion.

Table 13 is a matrix of the results of the tests which were conducted. Included in this table is the sample size, the maximum, minimum, and mean values of the force or work term, and the standard deviations of these quantities. The force terms recorded in this table are the maximum values of force sustained by the particular element.

Table 14 contains the results for the force corresponding to a prescribed (Fig 2) arming displacement of the slider of 0.104 inches. Typical static force-displacement curves are shown in Figures 24 through 27. The area under these curves is equal to the work or energy required to move the slider to the particular position.

Figure 24 shows a force-displacement trace for the static test-to-failure of the original firing pin. The peak force occurs during shear of the pin tip. A slightly different trace is obtained when the static load is applied on the slider against the new delay holder (Fig 25). The force identified in this test is related to the gouging of the arming pin on the end

Table 13

Static testing Matrix, maximum force and work values

COMPONENT		TEST FIXTURE				FUZE ASSEMBLY													
PULL WIRE	ORIGINAL																		
	NEW (LONG)									X	X	X	X						
DELAY HOLDER	ORIGINAL			X			X				X								X
	NEW (Ribbed)				X			X		X		X						X	
FIRING PIN	ORIGINAL	X				X					X	X							X
	REDESIGN #1		X						X	X								X	
	REDESIGN #2														X				
	REDESIGN #3													X					
	REDESIGN #4																X		
	REDESIGN #5															X			
PEAK FORCE	MAX.	45.5	100	61.5	122	92.0	119	156	145	462	312	418	159	625	161	650	462	250	82
	MIN.	25.0	90.0	43.0	78.0	60.0	69.0	95.0	101	299	212	305	128	430	110	525	340	165	34
PEAK FORCE (LB.)	AVERAGE	32.8	96.0	52.5	96.4	74.3	91.7	119	113	351	256	350	145	482	132.4	600	410	214	57.6
	STANDARD DEVIATION	6.6	2.71	6.96	18.1	9.87	13.8	17.2	10.1	37.6	39.6	33.6	9.10	73.8	10.7	39.7	44.4	31.0	15.0
WORK	MAX.	0.99	2.99	11.0	22.2	2.81	24.3	30.3	3.54	218	53.9	141	29.9	80.0	3.93	64.8	56.5	76.2	15.9
	MIN.	0.41	2.14	5.11	13.8	1.54	14.8	14.8	1.53	125	16.6	88.2	15.3	54.7	2.51	50.6	44.5	46.7	9.76
WORK TO MOVE SLIDER TO SQ POSITION (IN. LBS)	AVERAGE	0.66	2.59	8.88	17.4	2.15	18.6	22.7	2.67	16.8	38.4	111	22.2	64.0	3.40	57.7	52.6	59.7	13.2
	STANDARD DEVIATION	0.21	0.23	2.43	3.05	0.39	2.56	4.22	0.43	20.0	11.5	16.0	3.63	8.03	0.39	4.36	4.38	9.15	2.62
NUMBER TESTED		10	20	5	5	10	9	20	20	20	9	20	24	9	22	20	6	9	10
TEST LETTER DESIGNATION		A	D	B	C	A'	B'	C'	F or D'	E	G	H	I	K	J	M	O	L	N

Table 14

Static test results for slider motion of 0.104 inch in complete fuze assembly

COMPONENT		TEST FIXTURE					FUZE ASSEMBLY				
NEW PULL WIRE (LONG)		X	X	X							X
DELAY HOLDER	ORIGINAL		X			X		X			
	NEW RIBBED	X		X	X				X		
FIRING PIN	ORIGINAL		X	X		X	X				
	RD #1	X			X					X	
PEAK FORCE	MAX.	460	290	375	250	82.0	92.0	115	156	145	158
	MEAN	327	246	292	214	59.1	74.3	87.4	116	113	127
	MIN	260	190	230	165	34.0	60.0	69.0	93	101	106
	STD. DEV.	37.6	39.6	33.6	31.0	15.0	9.87	12.4	17.4	10.1	14.9
WORK TO MOVE SLIDER INTO SQ. POSITION	MAX.	26.3	14.0	20.7	13.6	6.40	2.81	7.50	11.3	3.54	9.60
	MEAN	14.5	11.0	14.0	11.2	5.38	2.15	5.95	9.13	2.67	5.12
	MIN.	8.5	6.90	10.2	8.4	4.20	1.54	4.90	6.50	1.53	3.20
	STD. DEV.	4.22	2.39	3.37	1.91	0.88	0.39	0.76	1.26	0.43	1.95
NUMBER TESTED		20	9	20	9	10	10	9	20	20	24
TEST LETTER DESIGNATION		E	G	H	L	N	A'	B'	C'	F	I

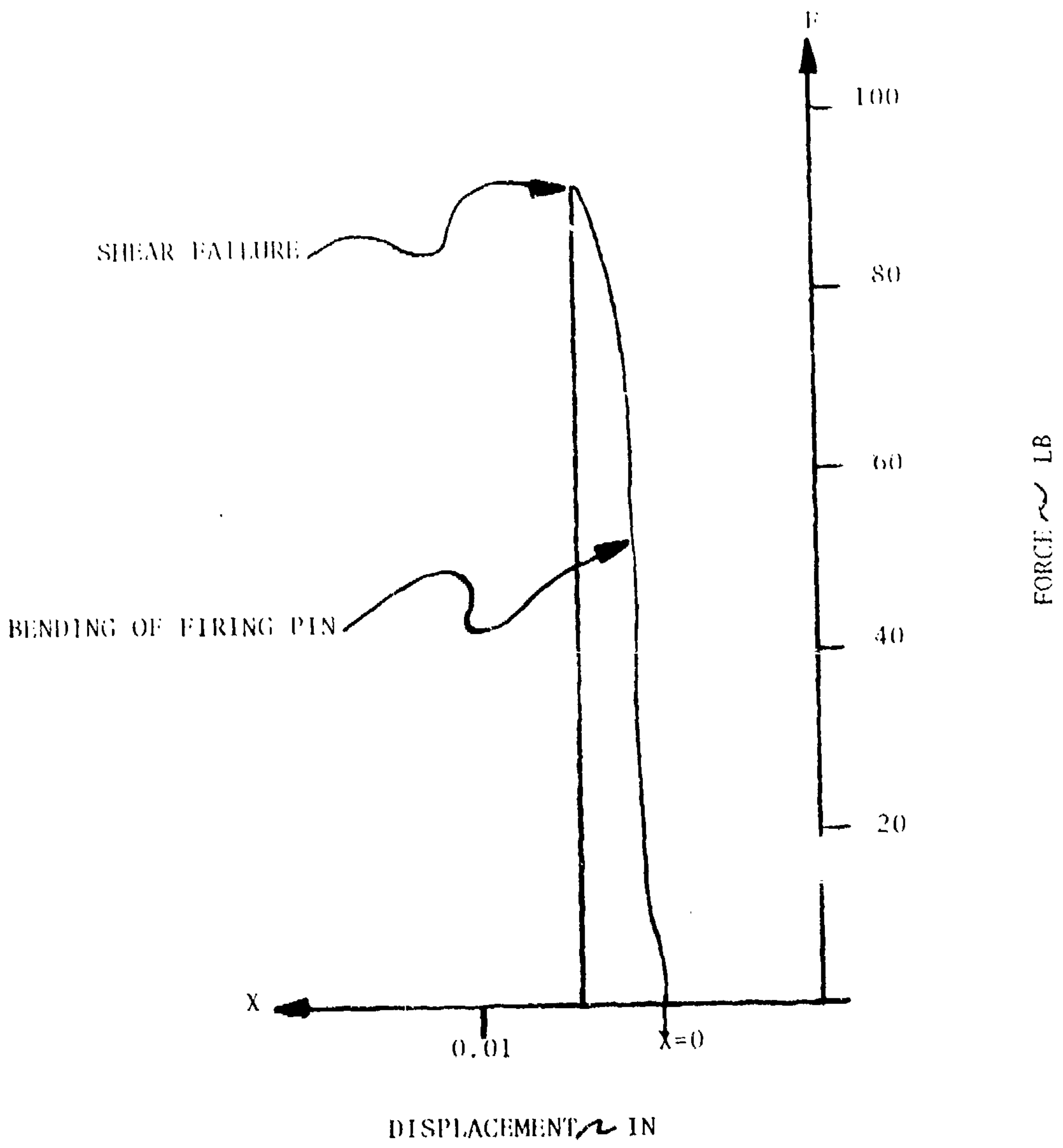


Fig 24 Original firing pin

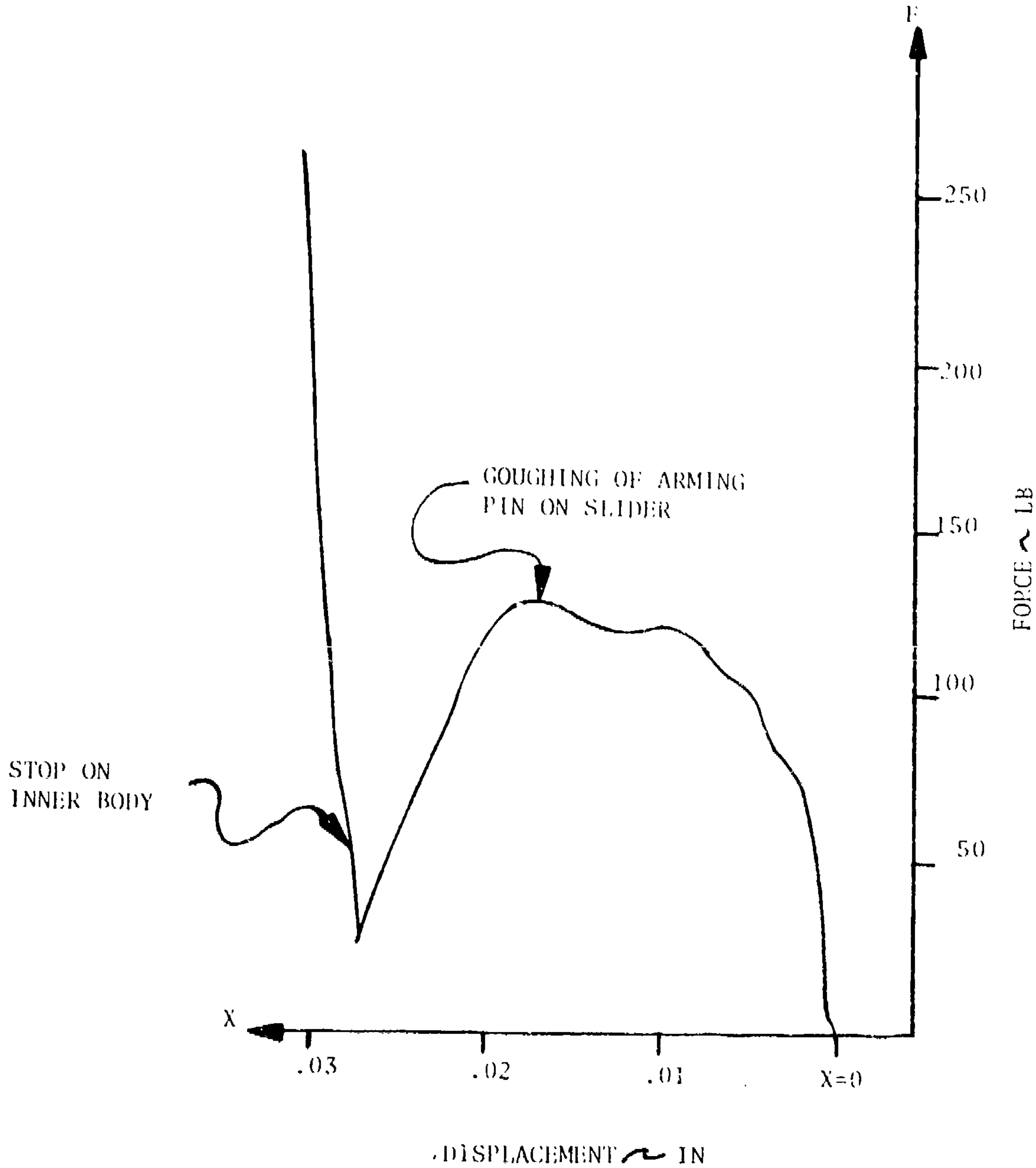


Fig 25 New delay holder

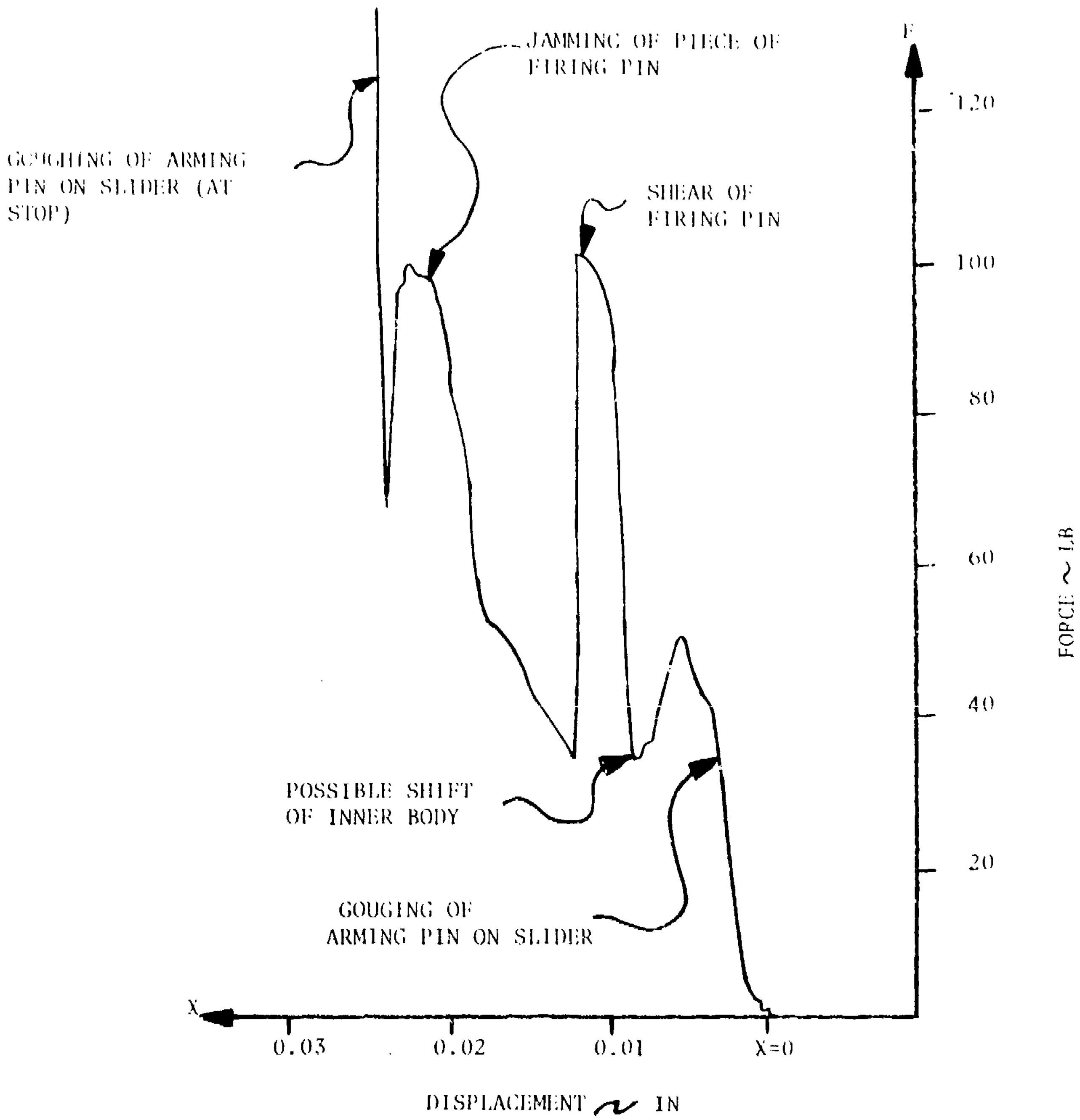


Fig 26 Original delay holder-original firing pin

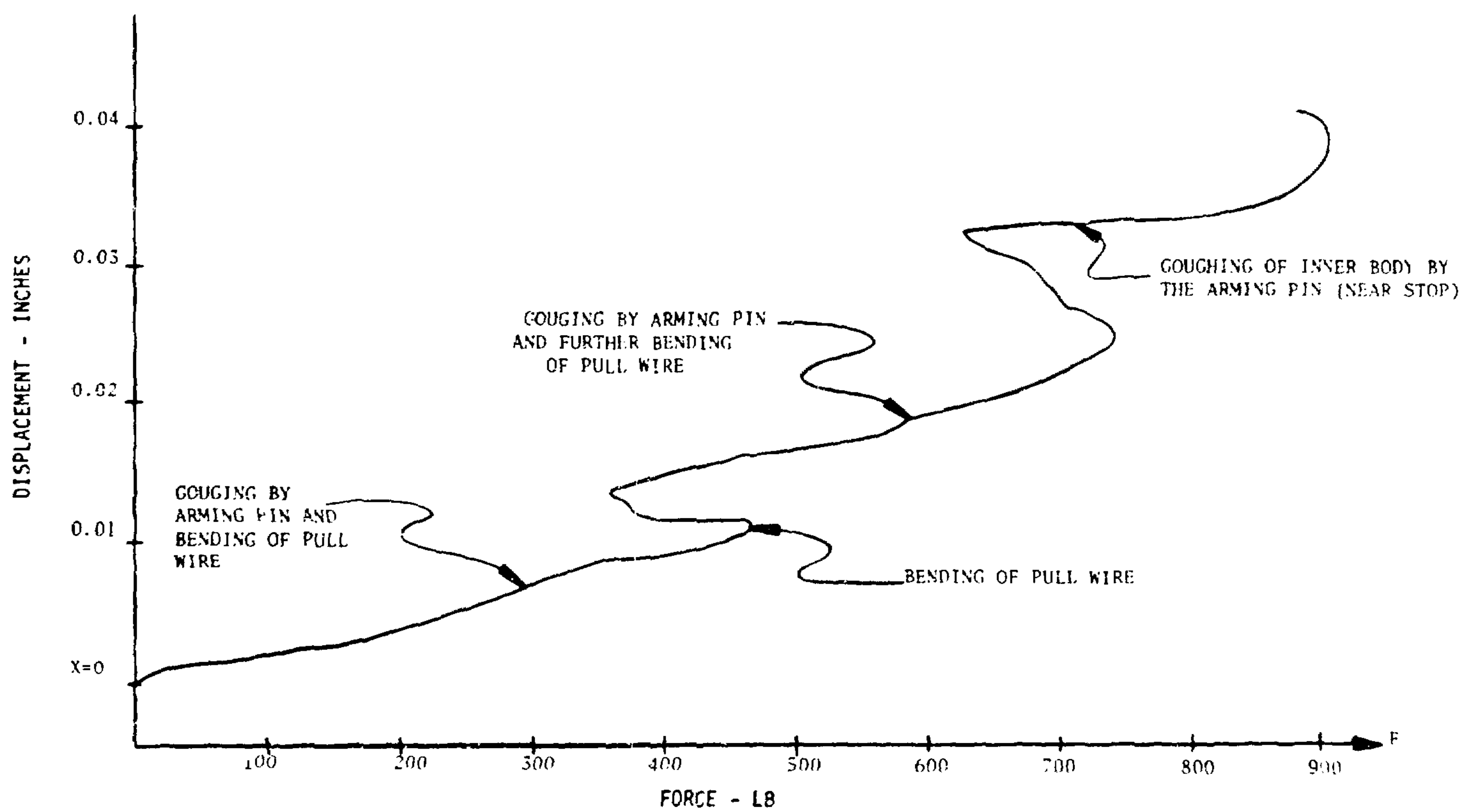


Fig 27 New pull wire and delay holder, firing pin RD No. 1

plate before the slider is moved against the stop (the inner body). The trace becomes more complex when two safeties are present (Fig 26). The first peak force on the trace appears as the arming pin gouges the slider. The decrease in the resisting force is probably due to a shifting of the inner body, thus easing the forced displacement of the slider inward. The force soon increases in magnitude as the slider bends the firing pin and reaches its peak of shear failure of the firing pin. A third peak occurs (present only when testing with the original firing-pin design) when the firing-pin tip shears off and jams the slider movement inward. The arming pin gouging of the slider is present throughout to a varying degree, until the slider reaches the inner body stop, and the resisting force magnitude increases rapidly.

The first peak force value was recorded and data dispersion was obtained from it. Beyond that peak, the force profile is a representation of a combination of events which take place and, hence, an evaluation of individual safeties is not possible. The work done to subvert both safeties was measured by evaluating the area under the curve from the initial displacement to the point corresponding to the slider position to meet the arming criteria as identified in Figure 2.

The static force displacement profile, obtained when all three safeties are present, is shown in Figure 27. The initial resisting force is a combination of bending of the pull wire, gouging of the slider by the arming pin, and bending of the firing pin, culminating in the first peak as the firing pin failure point is reached and a "mechanism" is formed. The resisting force soon resumes its climb by the further bending of the pull wire and the continued gouging by the arming pin. A decrease in the force (second peak) takes place, probably due to the shifting of the inner body halves against the slider, and the force reaches its final peak when the slider reaches the inner body stop. It may be observed that there are significant differences between the force levels found when testing an element in the test fixture and those found when testing the element in the fuze.

Comparison of Test of Fuze Elements in Test Fixture With Tests in Complete Fuze Assembly

A comparison was made among the static test values for force and work, for Tests E, G, H, L, and N, using the arming force values in Table 14. The criterion used was summation of element values and assembly value. The results are shown below. In all cases, the values of the force or energy terms for the complete assembly are less than the values for the force or energy corresponding to the sum of the individual components.

Table 15 Test G

	FORCE			ENERGY		
	MIN	AVG	MAX	MIN	AVG	MAX
A' - Original firing pin	60	74	92	1.54	2.15	2.81
I - New pull wire	106	127	158	3.2	5.1	9.6
B' - Original holder	69	87	115	4.9	6.0	7.5
G - Assy of items above	190	246	290	6.9	11.0	14.0

Force Analysis Using Average Values, Test G

$$A' + I + B' = 74 + 127 + 87 = 288 > 246$$

$$G - I - B' \stackrel{?}{=} A'$$

$$246 - 127 - 87 = 32 < 74 = A'$$

$$G - B' - A' \stackrel{?}{=} I$$

$$246 - 87 - 74 = 85 < 127 = I$$

$$G - I - A' \stackrel{?}{=} B'$$

$$246 - 127 - 74 = 45 < 87 = B'$$

Energy Analysis Using Average Values, Test G

$$A' + I + B' = 2.15 + 5.1 + 6.0 = 13.25 > 11.0$$

$$G - I - B' \stackrel{?}{=} A$$

$$11.0 - 5.1 - 6.0 \sim 0 < 2.15 = A'$$

$$G - B' - A' \stackrel{?}{=} I$$

$$11.0 - 6.0 - 2.15 = 2.85 < 5.1 = I$$

$$G - I - A' \stackrel{?}{=} B'$$

$$11.0 - 5.1 - 2.15 = 3.75 < 6.0 = B'$$

Table 16 Test E

	FORCE			ENERGY		
	MIN	AVG	MAX	MIN	AVG	MAX
F - RD No. 1 firing pin	101	113	145	1.53	2.7	3.54
I - New pull wire (LONG)	106	127	158	3.2	5.1	9.6
C' - New holder (RIBBED)	93	116	156	6.5	9.1	11.3
E - Assy of items above	260	327	460	8.5	14.5	26.3

Force Analysis Using Average Values, Test E

$$F + I + C' = 113 + 127 + 116 = 356 > 327$$

$$E - I - C' \overset{?}{=} F$$

$$327 - 127 - 116 = 84 < 113 = F$$

$$E - C' - F \overset{?}{=} I$$

$$327 - 116 - 113 = 98 < 127 = I$$

$$E - I - F \overset{?}{=} C'$$

$$327 - 127 - 113 = 87 < 116 = C'$$

Energy Analysis Using Average Values, Test E

$$F + I + C' = 2.7 + 5.1 + 9.1 = 16.9 > 14.5$$

$$E - I - C' \overset{?}{=} F$$

$$14.5 - 5.1 - 9.1 = 0.3 < 2.7$$

$$E - C' - F \overset{?}{=} I$$

$$14.5 - 9.1 - 2.7 = 2.7 < 5.1$$

$$E - I - F \overset{?}{=} C'$$

$$14.5 - 5.1 - 2.7 = 6.7 < 9.1$$

Table 17 Test L

	FORCE			ENERGY		
	MIN	AVG	MAX	MIN	AVG	MAX
F - RD No. 1 firing pin	101	113	145	1.53	2.7	3.54
C' - New holder, ribbed	93	116	156	6.5	9.1	11.3
L - Assy of items above	165	214	250	8.4	11.2	13.6

Force Analysis Using Average Values, Test L

$$F + C' = 113 + 116 = 229 > 214$$

$$L - F \stackrel{?}{=} C'$$

$$214 - 113 = 101 < 116 = C'$$

$$L - C' \stackrel{?}{=} F$$

$$214 - 116 = 98 < 113 = F$$

Energy Analysis Using Average Values, Test L

$$F + C' = 2.7 + 9.1 = 11.8 > 11.2$$

$$L - F \stackrel{?}{=} C'$$

$$11.2 - 2.7 = 8.5 < 9.1$$

$$L - C' \stackrel{?}{=} F$$

$$11.2 - 9.1 = 2.1 < 2.7$$

Table 18 Test N

	FORCE			ENERGY		
	MIN	AVG	MAX	MIN	AVG	MAX
A' - Original firing pin	60	74	92	1.54	2.15	2.81
B' - Original holder	69	87	115	4.9	6.0	7.5
N - Assy of items above	34	59	82	4.2	5.4	6.4

Force Analysis Using Average Values, Test N

$$A' + ' = 74 + 87 = 161 > 59$$

Energy Analysis Using Average Values, Test N

$$A' + B' = 2.15 + 6.0 = 8.15 > 5.4$$

Statistical Analysis of Static Test Data

Certain of the force and work terms contained in Tables 13 and 14 were analyzed statistically, as follows:

The first approach was to fit the data to an arithmetic normal distribution function whose cumulative normal probability distribution is characterized by

$$F(x) = \frac{1}{\sqrt{2\pi}\,\sigma} \int_{-\infty}^{x} e^{-\left(\frac{1}{2\sigma^2}\right)(x-\mu)^2}\, dx \tag{193}$$

and whose normal density distribution is characterized by

$$f(x) = \frac{1}{\sqrt{2\pi}\,\sigma}\, e^{-\left(\frac{1}{2\sigma^2}\right)(x-\mu)^2} \tag{194}$$

where μ = mean of distribution

and σ = standard deviation.

The various sets of data for the two continuous random variables, work and force, were plotted on an arithmetic normal probability paper. Results indicated that a theoretical arithmetic normal distribution function did not best-fit the data points. A log-normal probability distribution function was subsequently selected to fit the data, given by

$$F(x) = \frac{1}{\sqrt{2\pi}\,\sigma} \int_{-\infty}^{x} e^{-\left(\frac{1}{2\sigma^2}\right)(\log (x-\mu)^2)}\, dx \tag{195}$$

Results showed that the log-normal theoretical distribution was an improvement over the arithmetic normal but did not appear to satisfactorily describe the complete sets of data.

A third model, the Weibull distribution model, was next used. Its cumulative distribution is described by

$$F(x) = 1 - e^{-\left(\frac{x-\gamma}{\theta}\right)^{\alpha}} \tag{196}$$

and its density distribution function is

$$f(x) = \frac{\gamma\,(x - \gamma)^{\alpha-}}{\theta\,\alpha}\; e\left(\frac{x - \gamma}{\theta}\right)^{\alpha} \tag{197}$$

where γ = location parameter

θ = scale parameter

α = shape parameter

The model fit the sets of data rather well. A goodness of fit test, characterized by a linear plot of the empirical random variable versus the theoretical random variable, substantiated the adequacy of the Weibull model in characterizing the empirical distribution of the random variables. Figures 28 through 35 show the resulting cumulative probability function curves.

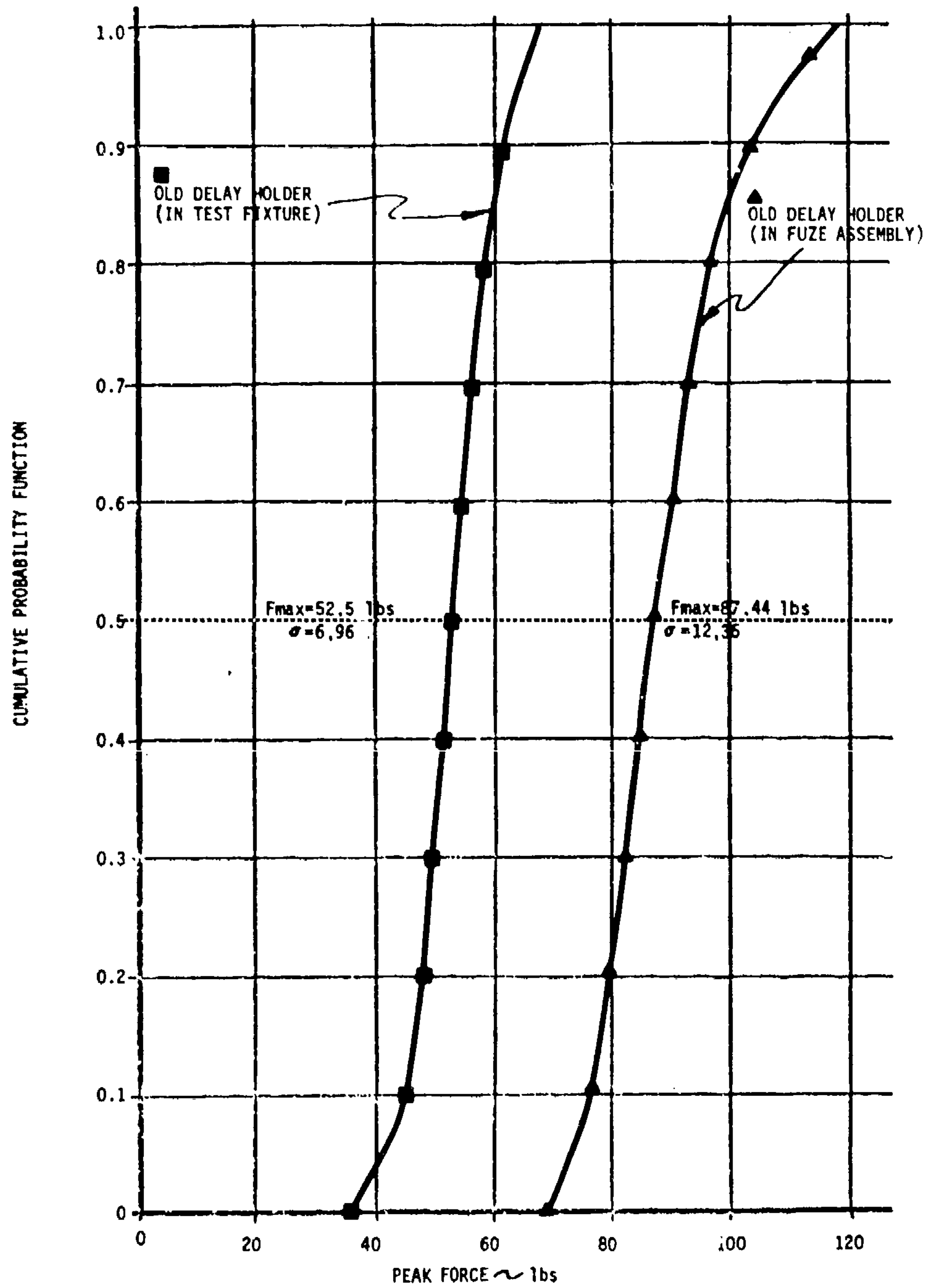


Fig 28 Cumulative distribution function comparison for the old delay holder

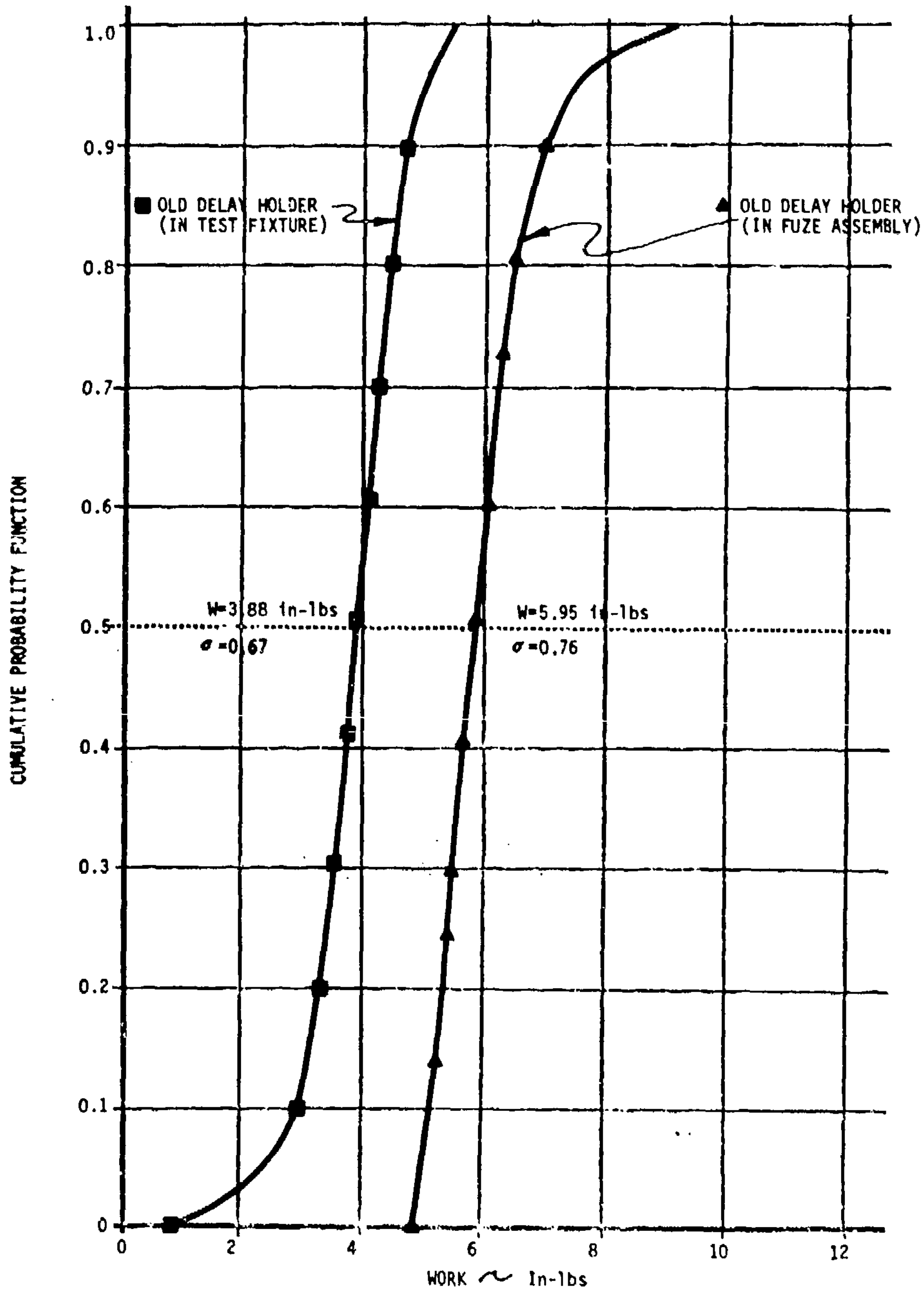


Fig 28 Cumulative distribution function comparison for the old delay holder (Cont)

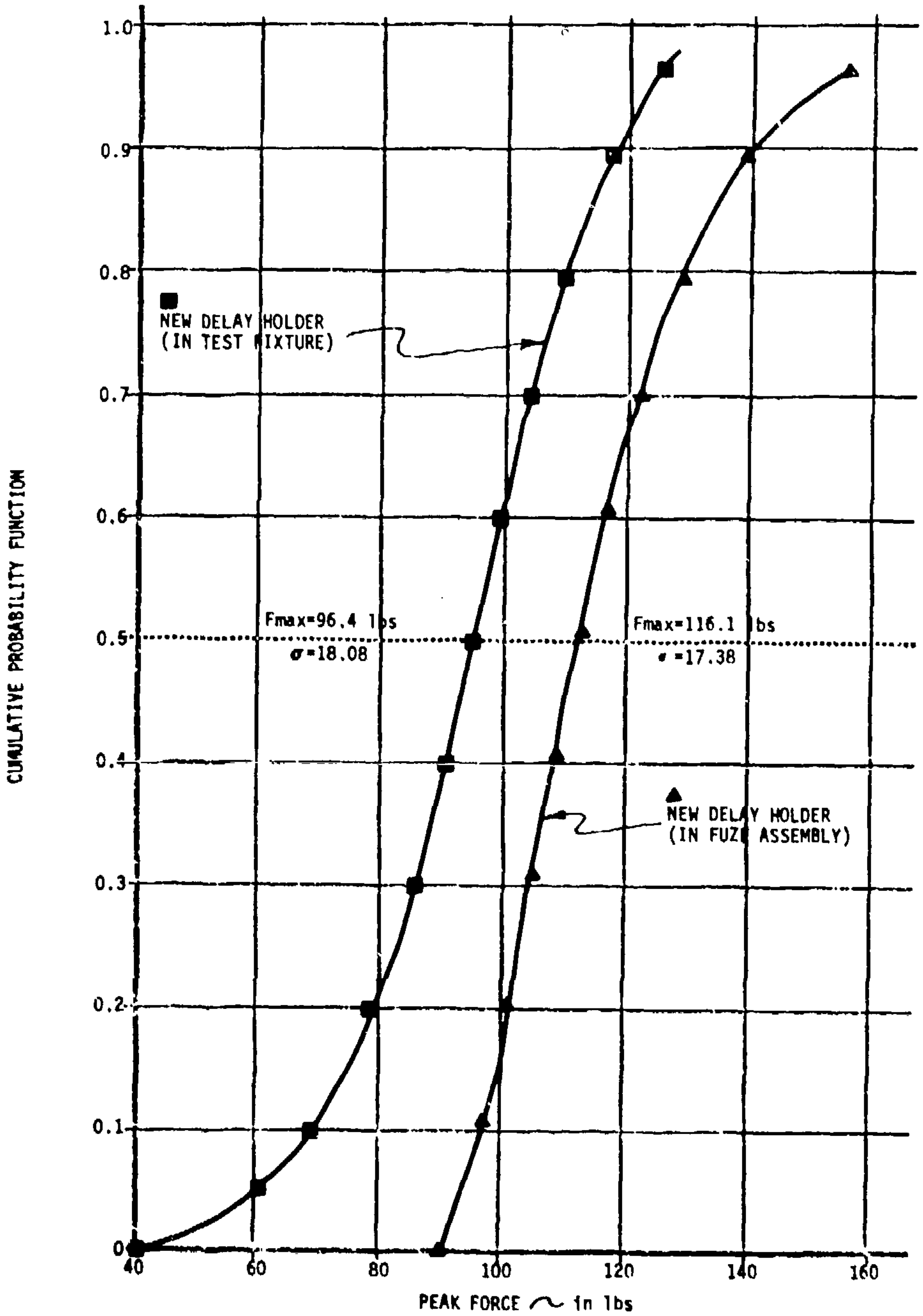


Fig 29 Cumulative distribution function comparison for the new delay holder

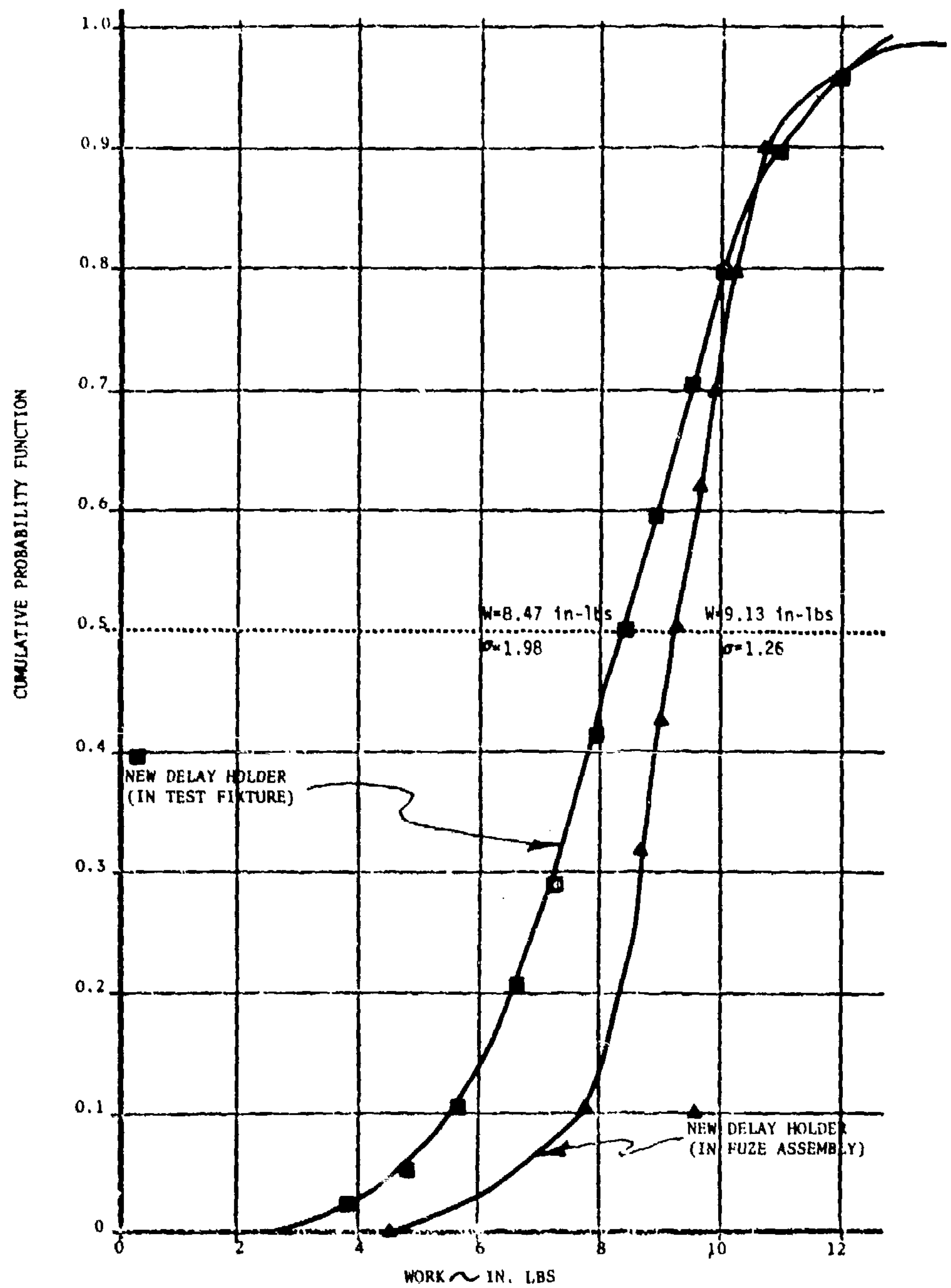


Fig 29 Cumulative distribution function comparison for the new delay holder (Cont)

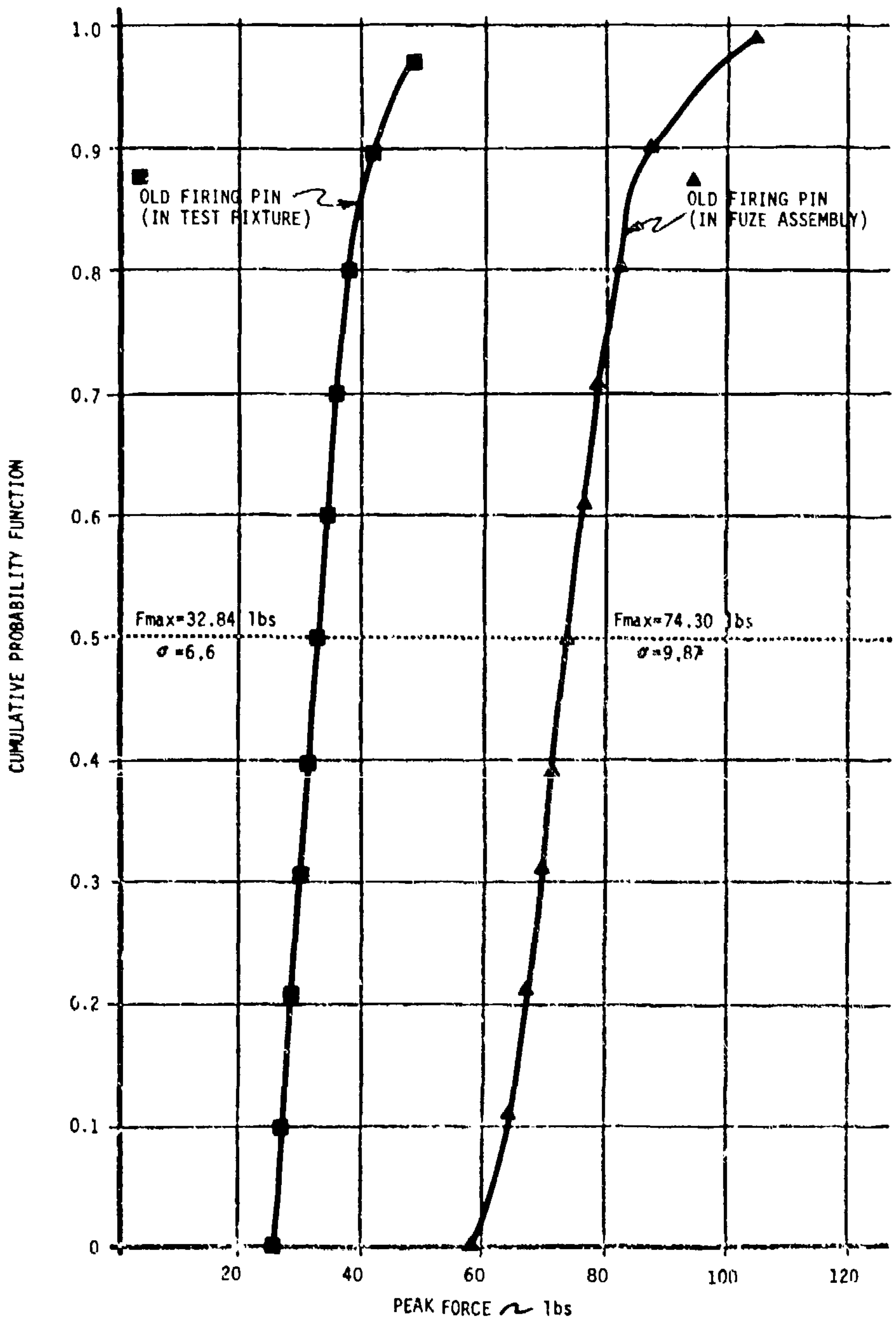


Fig 30 Cumulative distribution function comparison for the old firing pin

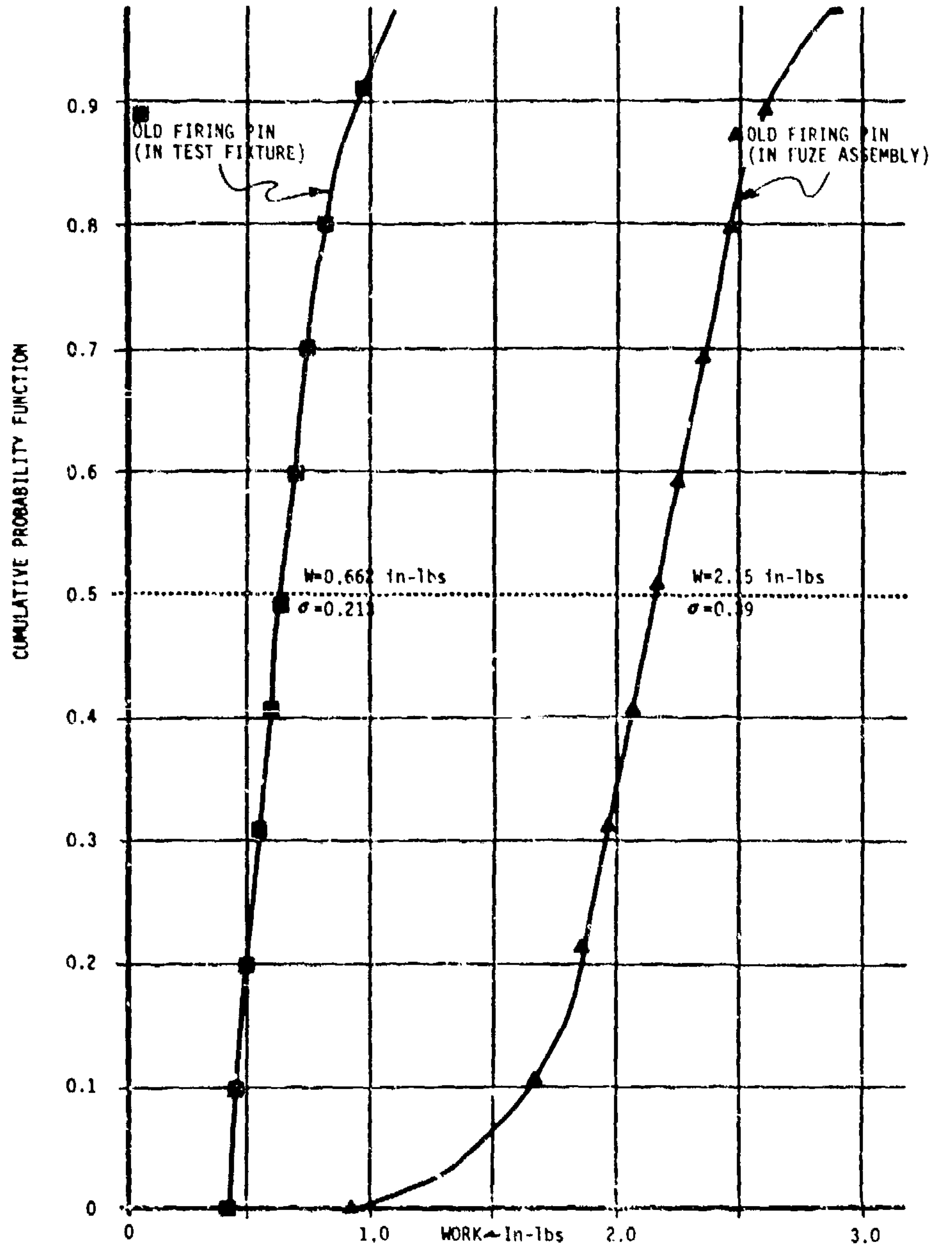


Fig 30 Cumulative distribution function comparison for the old firing pin (Cont)

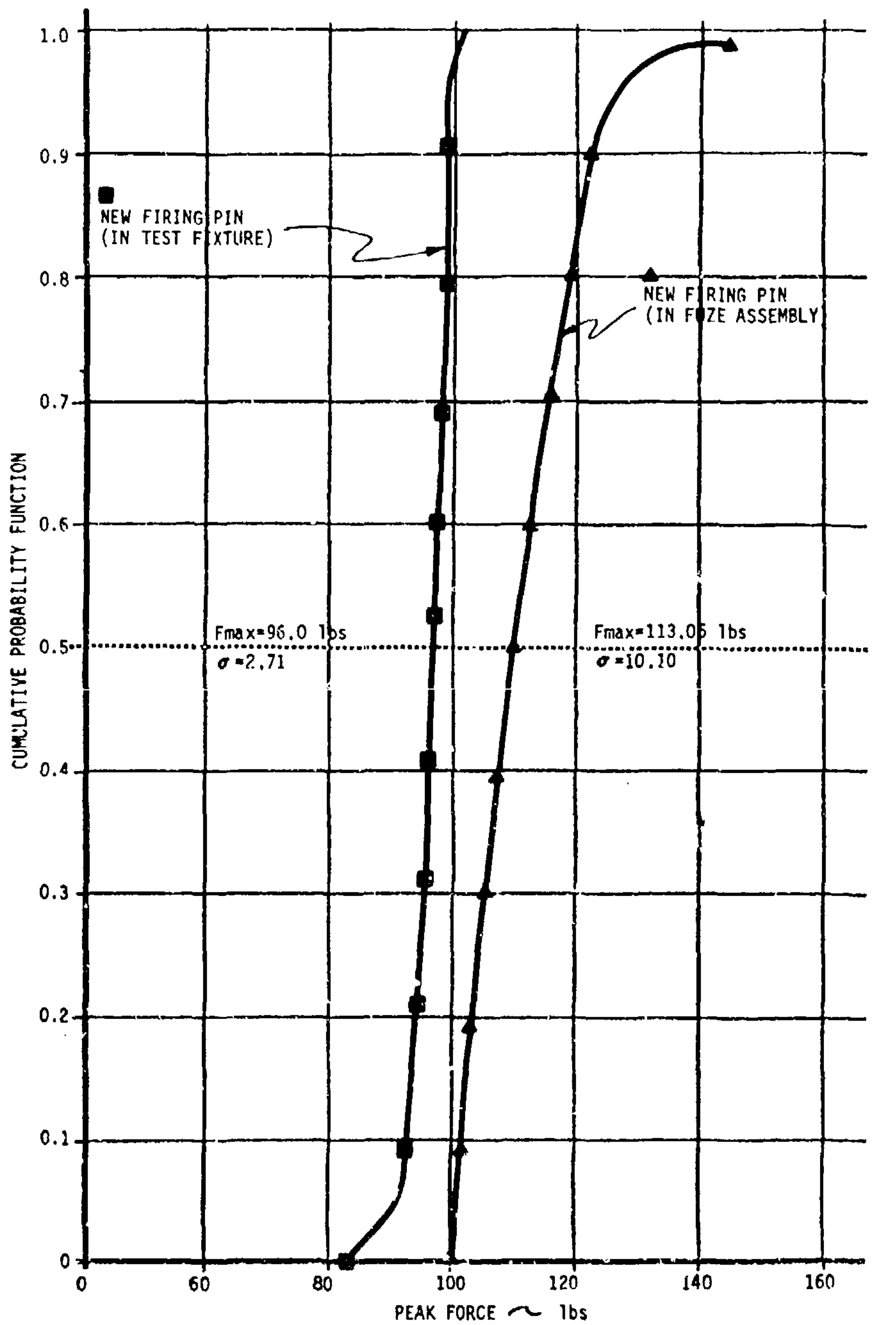


Fig 31 Cumulative distribution function comparison for the new firing pin (RD#1)

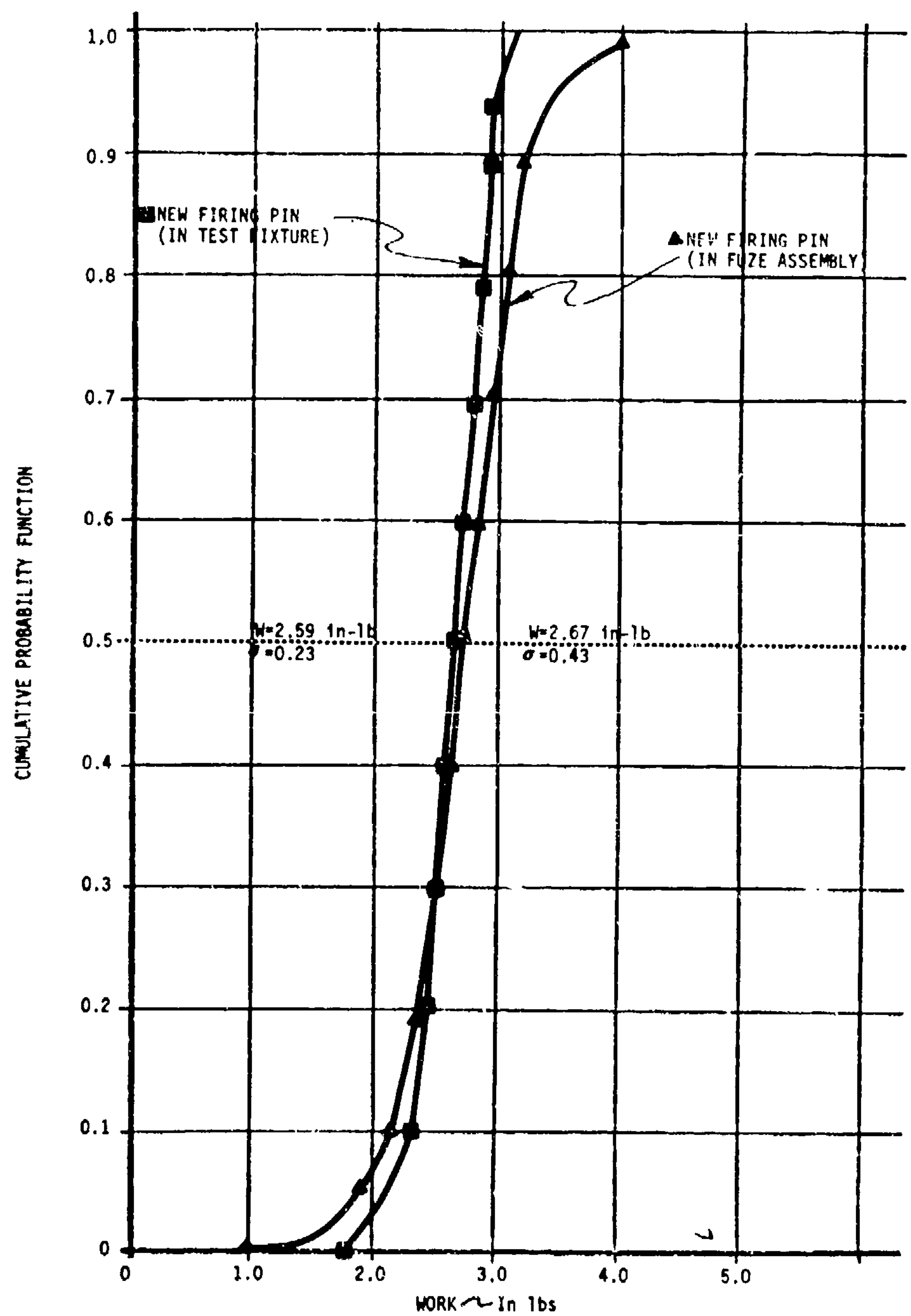


Fig 31 Cumulative distribution function comparison for the new firing pin (RD#1) (Cont)

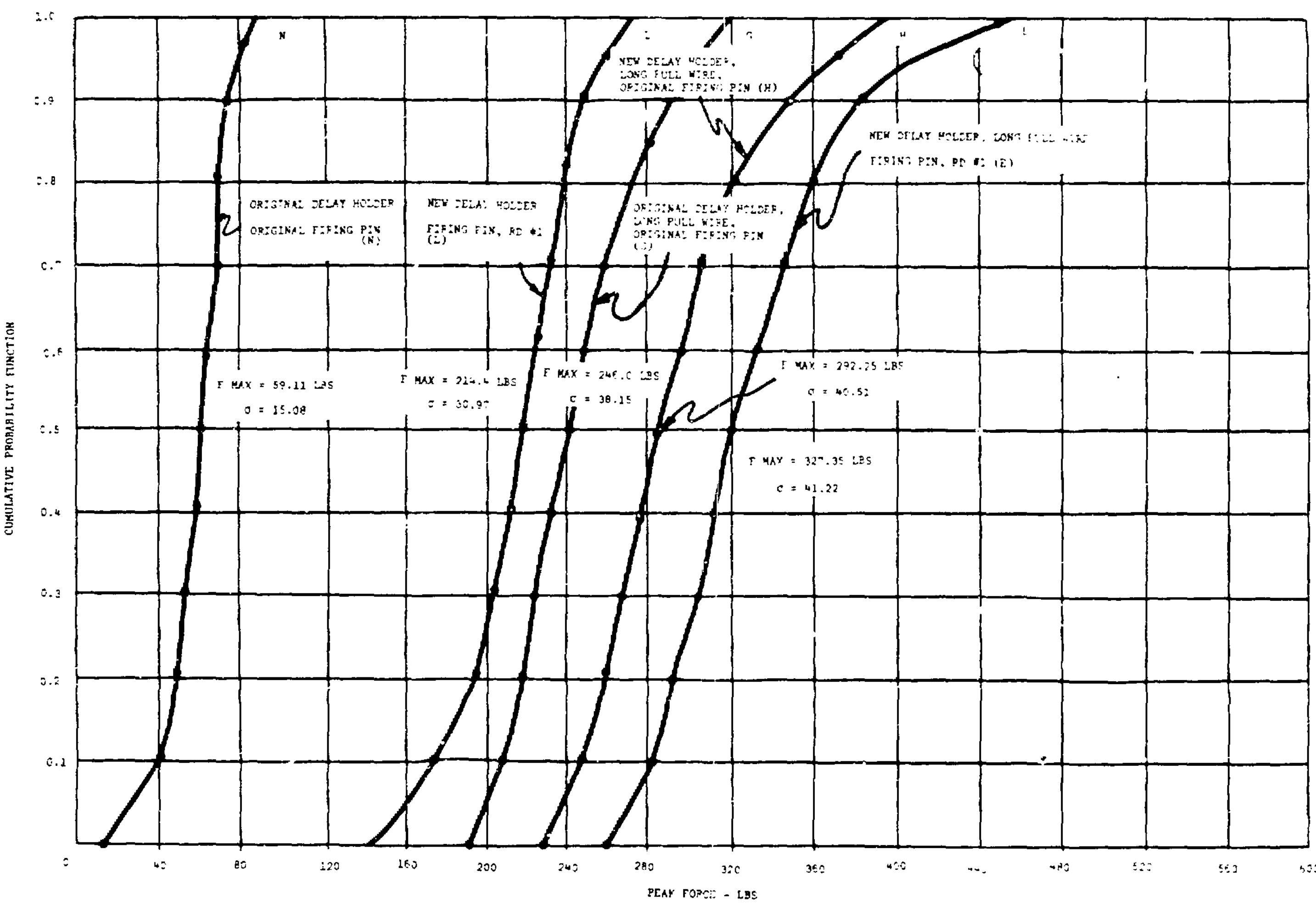


Fig 32 Cumulative distribution function comparison, tests E, G, H, L, N (peak force), fuze assembly

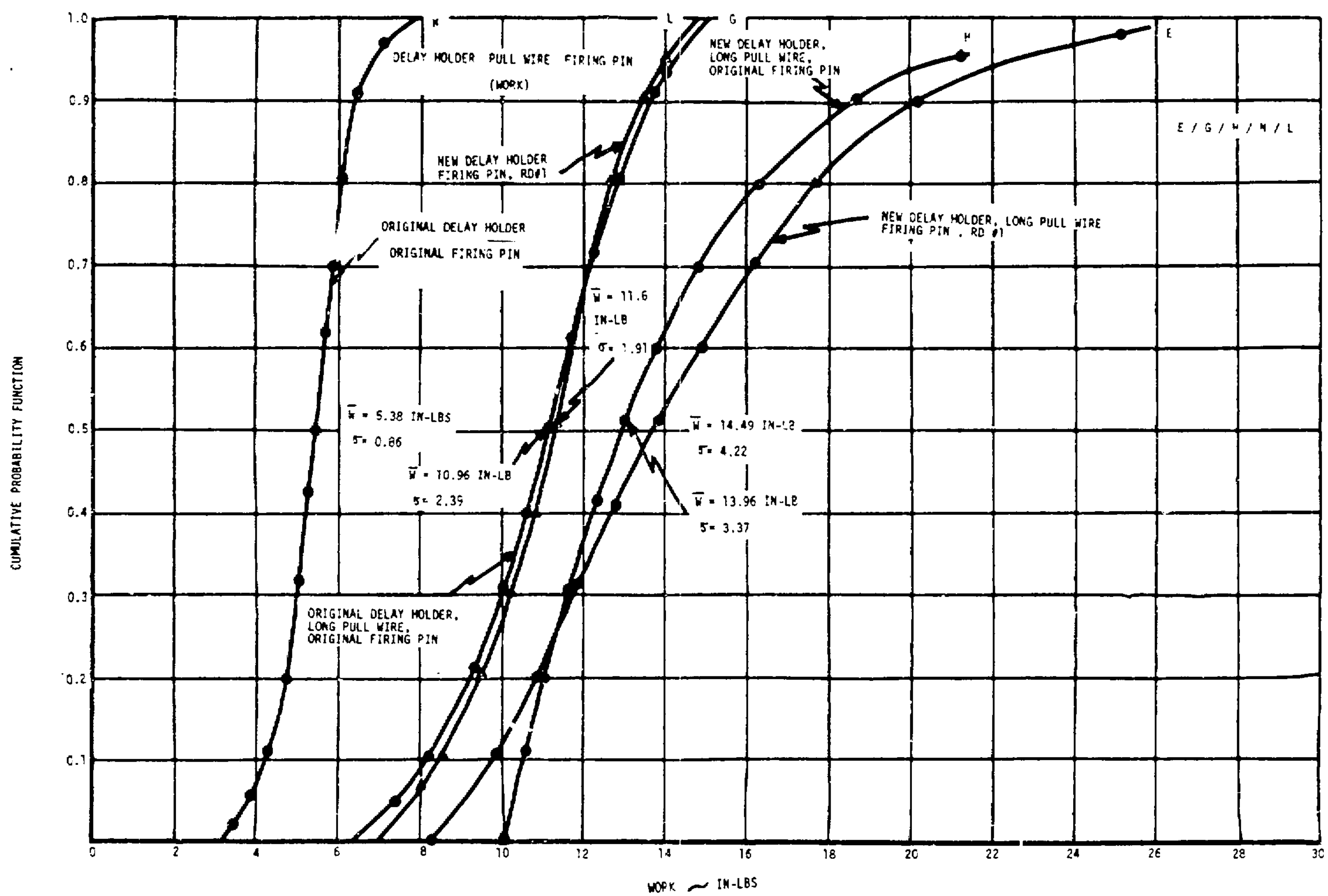


Fig 33 Cumulative distribution function comparison, tests E, G, H, L, N (work), fuze assembly

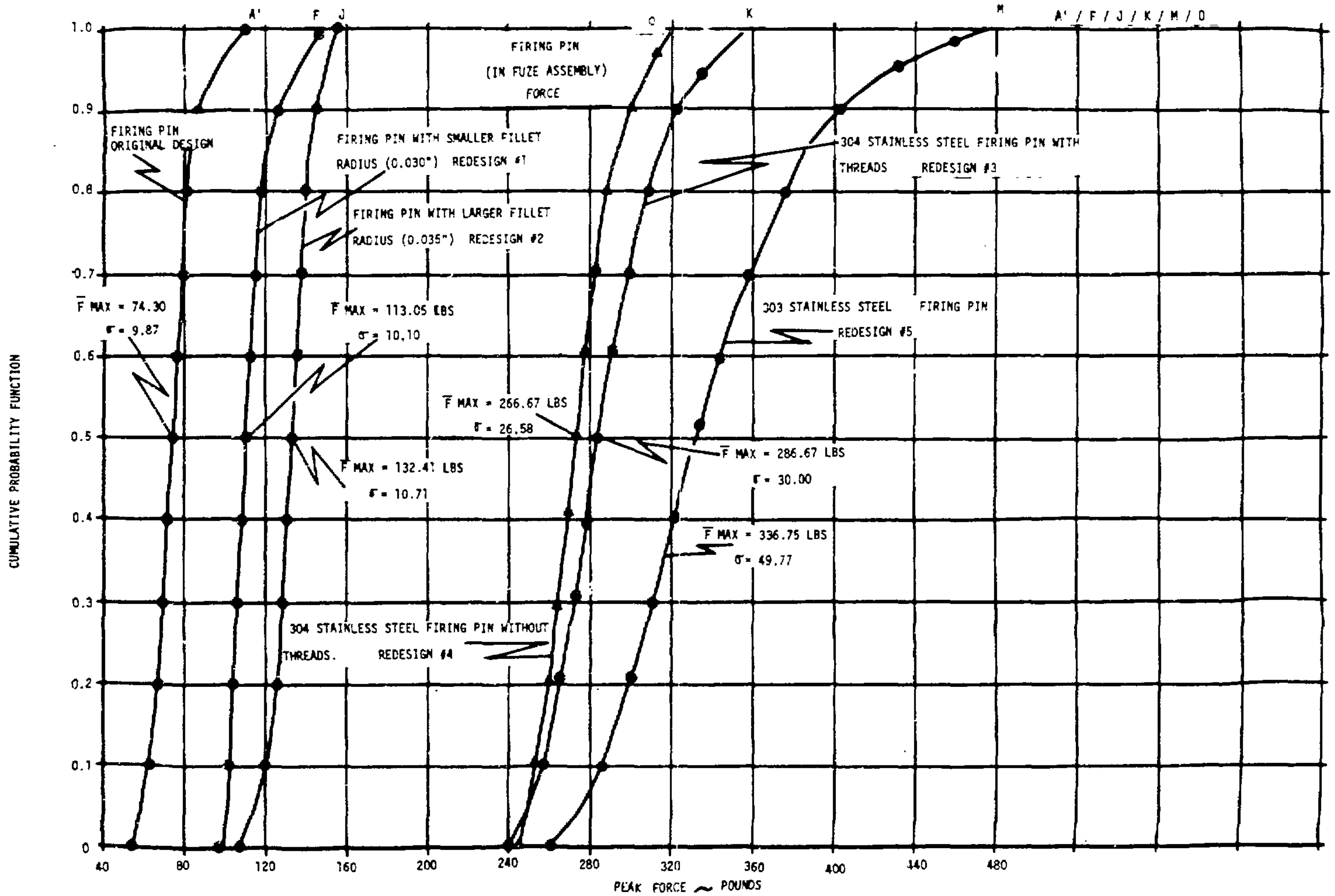


Fig 34 Cumulative distribution function comparison, firing pin tests (peak force), fire assembly

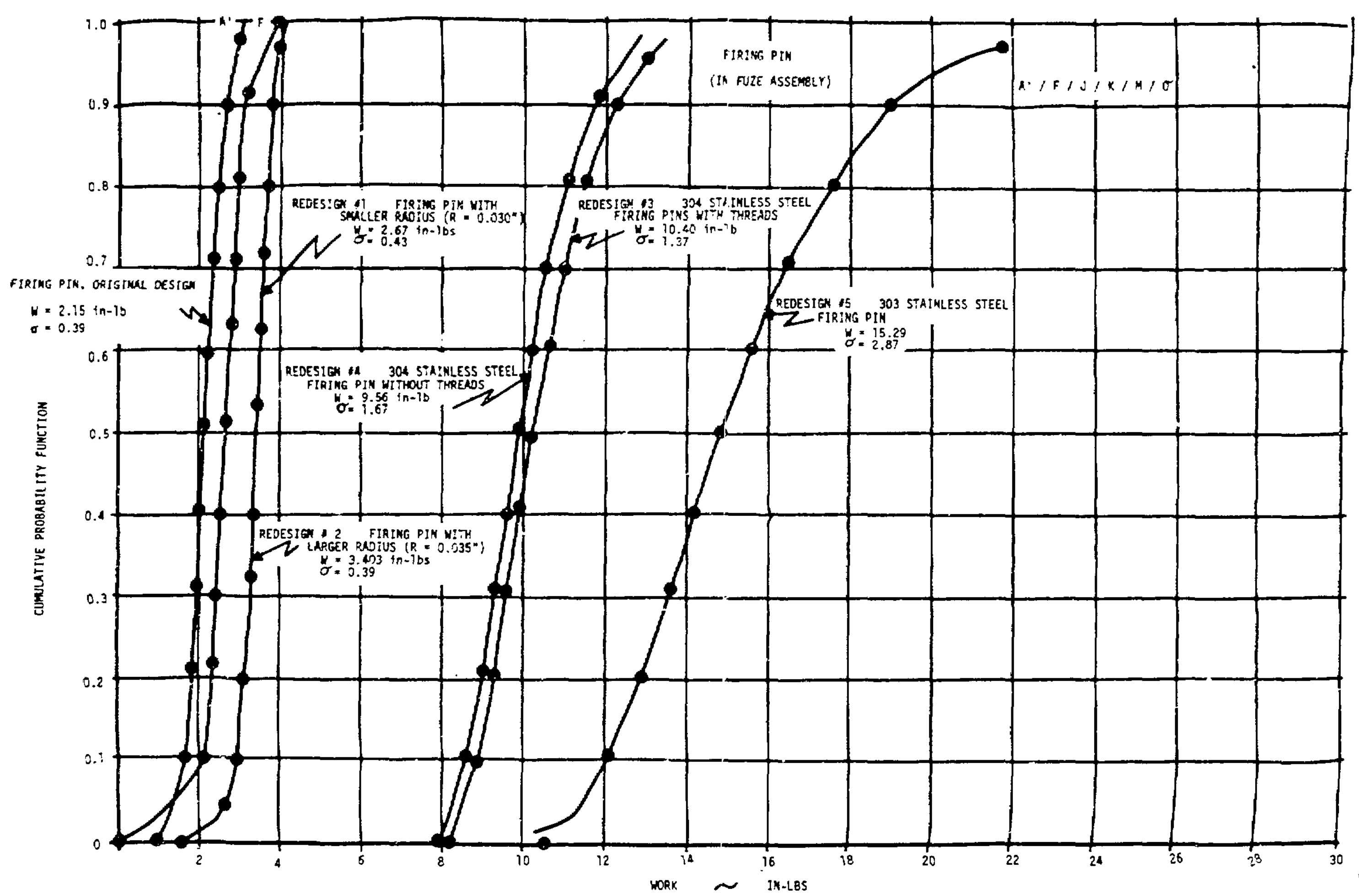


Fig 35 Cumulative distribution function comparison, firing pin tests (work), fuze assembly

Table 19

Summary of computed and experimental results

Item	Computed Min	Computed Avg	Computed Max	Experimental[e] Min	Experimental[e] Avg	Experimental[e] Max	Sample size
Maximum force on slider, with pull wire only	115[a]	184[a]	203[a]	128	145	159	24
Old firing pin (fixture)	24.1[b]	56[b]	95.8[b]	25.0	32.8	45.4	10
Rd No. 1, aluminum, small	91.5[c]	153[c]	215[c]	90	96	100	20
Radius (fixture)	104[d]	175[d]	245[d]				
Rd No. 2, aluminum, large	107[c]	253[c]	399[c]	110	132	161	22
Radius (fuze)	122[d]	288[d]	454[d]				
Rd No. 3, steel, threaded (fuze)	414[a]	762[a]	1511[a]	430	482	625	9
Rd No. 4, steel, magnaformed, (fuze)	414[a]	762[a]	1511[a]	340	410	462	6
Rd No. 5, steel, flanged head (fuze)	302[a]	567[a]	1923[a]	525	600	650	20
Energy to move slider to sq position, with pull wire only	11.4	14.4	16.3	15.3	22.2	27.9	24

[a]Plastic hinge failure

[b]Ultimate shear failure

[c]Yielding at outer fibers

[d]Ultimate tensile strength at outer fibers (assumption of modulus of rupture failure)

[e]"Experimental" forces are maximum values of force recorded in instrom test

Comparison and Discussion of Analytical and Experimental Static Results

A summary of the analytical and experimental results for static loading of the fuze and its components is presented in Table 19.

In the analysis of the static load (on the slider) required to bend the pull wire, the effect of local yielding of the contacting edges on the slider and on the holder was neglected. The effect of this local yielding would be to increase the bending moment arm of the pull wire and decrease the values of the forces computed previously. The initial configuration of the pull wire in the body is shown in Figure 36.

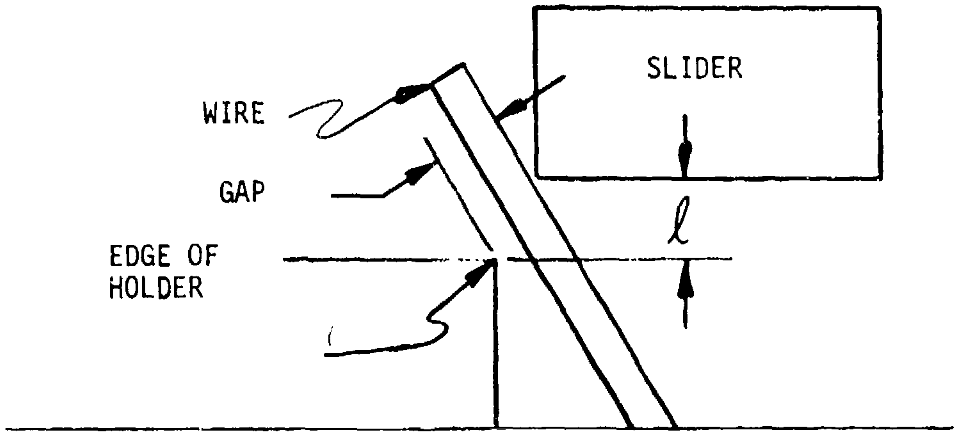


Fig 36 Initial pull wire configuration in the fuze body

The gap between the wire and the edge of the holder is assumed to be closed at low values of load on the slider, and the effect is neglected in this study. There is good agreement between the analytical and experimental values of slider load using the criteria: (1) computed minimum force compared with the experimental minimum force, and (2) computed maximum force compared with the experimental maximum force.

A comparison of the values for the firing pins RD No. 3 and RD No. 4 reveals that the magnaforming process seems to be weaker than screwing the insert into the holder. The manufacturing tolerances have a very significant effect on the range of both the computed and the experimental values of force and energy. In all the tests (E, G, H, L and N), the strength of the assembly is consistently less than the sum of the strengths of the individual components of the assembly. The same holds true for the energy comparison. On the basis of these results, the only valid method of testing the slider force is with all of the components in position.

It appears that there is an interactive effect among the elements of the fuze, and that this effect cannot be predicted quantitatively by testing the individual components of the fuze.

In the development of the energy model of pull wire bending, the elastic-strain energy of bending is neglected, and only the work of plastic bending is considered. The analytical results for the energy required are considerably less than those obtained in the test. This is probably due to the increase in the effective coefficient of friction of the mating surfaces, which are gouged as the loading continues.

All of the calculations in this report are based on the assumption that the slider is in the superquick position. For the case where the slider is dropped in a most unfavorable configuration, with the slider in the delay position, the moment arm for bending of the pull wire is increased, as shown in Figure 37. This effect is due to the flat on the slider.

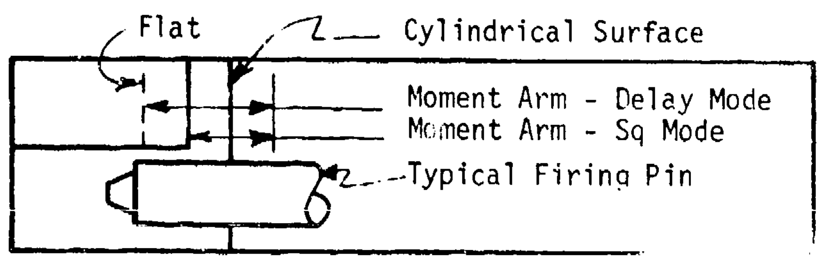


Fig 37 Moment-over depiction for delay modes

In order for the slider to achieve the armed position, three safety mechanisms must be overcome. These are:

1. The pull wire
2. The arming pin (delay holder)
3. The firing pin

The present study did not take into account the order in which these elements failed.

CONCLUSIONS

1. M567 fuzes produced until November of 1975, retrofitted only with long pull wires, were found to meet the safety requirements for which they were designed (App I). The margin of safety over the requirements

was later found to be less than desired. Pull wires were originally intended to guard against mortar signature accelerations which could occur in certain handling environments, (e.g., malfunctioning parachute delivery).

2. The sequential rough handling tests specified by TECOM in qualifying the lightweight company mortar (LWCM) (App J) are more severe on the XM935 fuze than was the sequential rough handling test to which the M567 was subjected during DT/OT II (Tables 6, 7).

3. When failures were induced, the failure mechanism was initiated by having the internal clearances between certain parts in the fuze become greater, thus reducing the interference between the delay element holder and the slider and permitting the slider to bypass the arming pin safety and contact the firing pin which was not strong enough to restrict further movement of the slider.

4. The design changes introduced prevent the relative motion of presumably fixed internal parts and increase the strength of the firing pin tip by an order of magnitude. The result of this is a completely safe fuze under any rough handling conditions to which it has been subjected, including the destruction of the mortar round (100-foot drop test). As long as the firing pin and the delay element holder are present as safeties, the pull wire is not required. This latter element is required only for the malfunctioning parachute drop test.

5. The XM935E2, an interim design for the DT/OT II of the LWCM, has a safety margin which is more than adequate for these tests. It also has a "fail safe" firing pin tip. This design is less strong than the design planned for subsequent production, and it does require the pull wire for shipment.

6. The stockpile of M567 fuzes, produced up to November 1975, can be retrofitted with new firing pins and pinned inner bodies. This design change only, without pull wires, will enable these items to pass the newer, more severe rough-handling tests with an adequate margin of safety.

RECOMMENDATIONS

1. In order to increase the margin of safety, five design changes are recommended for future fuze production. None of these designs reflect major changes in either the basic features of the design or in the functional

characteristics of the components. Specifically, the recommendations includes:

a. Adding two diagonal ribs, 0.023 inch wide by 0.025 inch high, to the delay-element holder, as shown in Figure 38.

b. Adding two nibs to the spacers and increasing the size of the original nibs on this element, as shown in Figure 39.

c. Pinning the two body halves together with a pressed spiral pin, 0.062 inch in diameter, as shown in Figure 40.

d. Changing the slider material from die casting zinc AQ40A to AQ41A to improve the compression and shear strengths.

e. Changing the firing pin to Redesign No. 5, aluminum shank with a threaded flanged-steel tip, Dwg. XM 720-036, as shown in Figure 18.

2. For rework of existing stockpile items, the combination of Case 3, (pinning of the body halves) and Case 5 (replacing the firing pin) is recommended. The costs of this effort are presently being developed.

3. It is also recommended that the differences between MIL-STD-331's acceptance tests and those required by TECOM be reconciled.

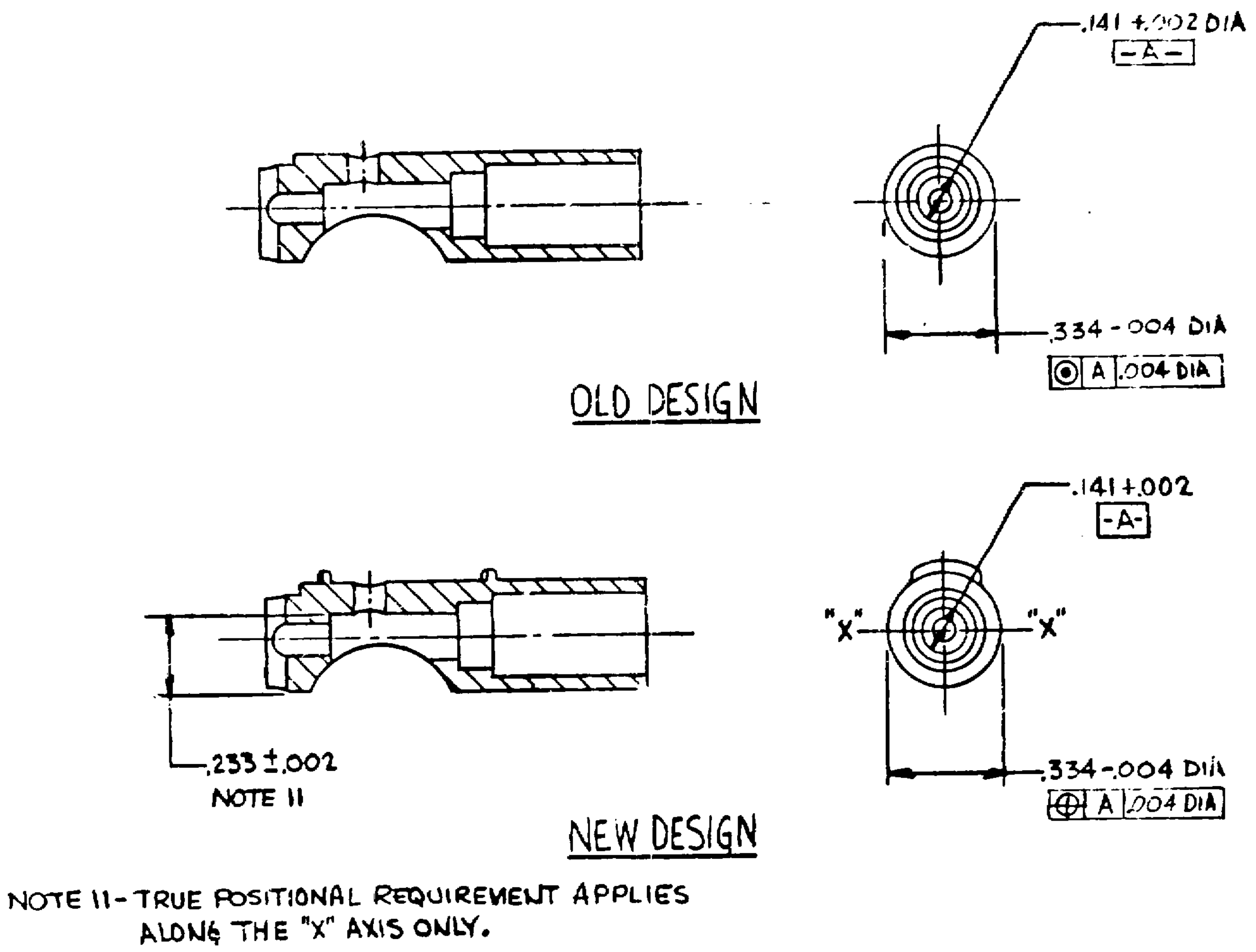


Fig 38 Delay-element holder

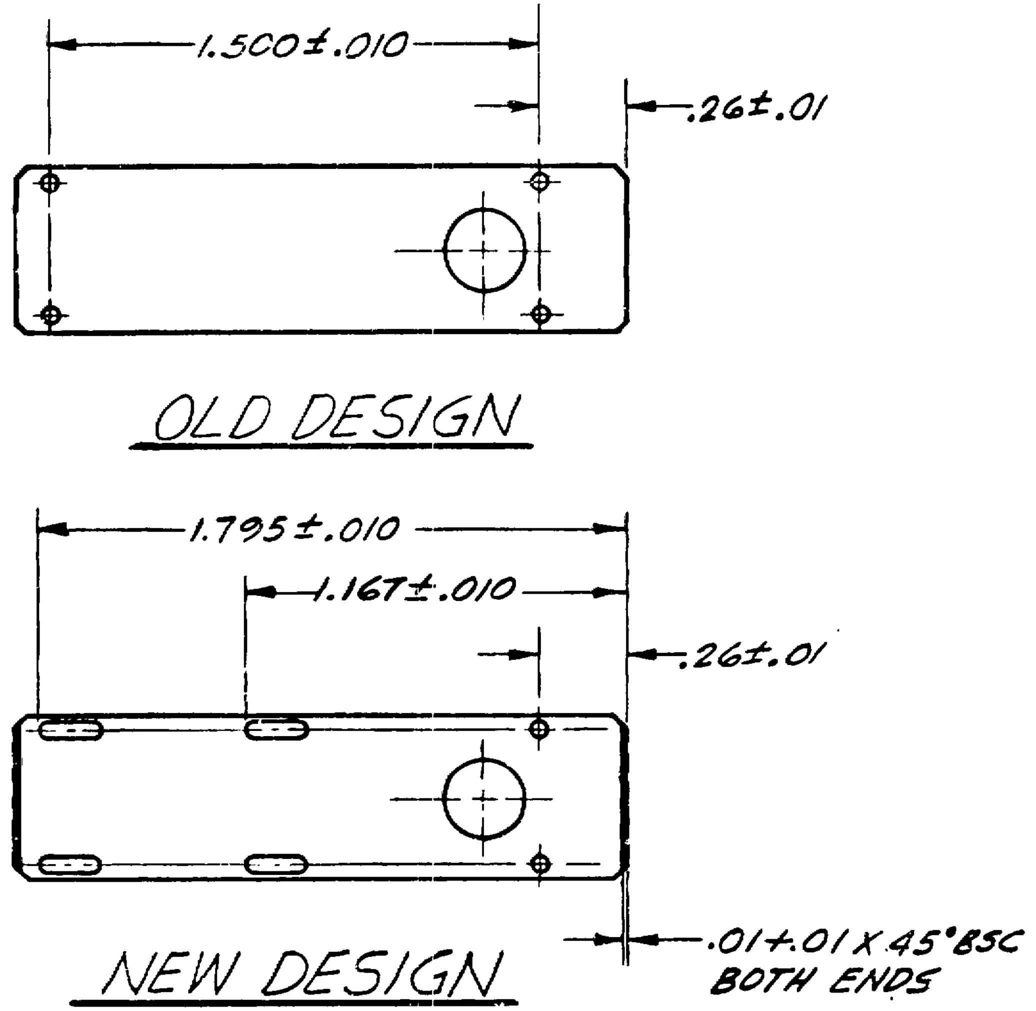


Fig 39 Front body spacer

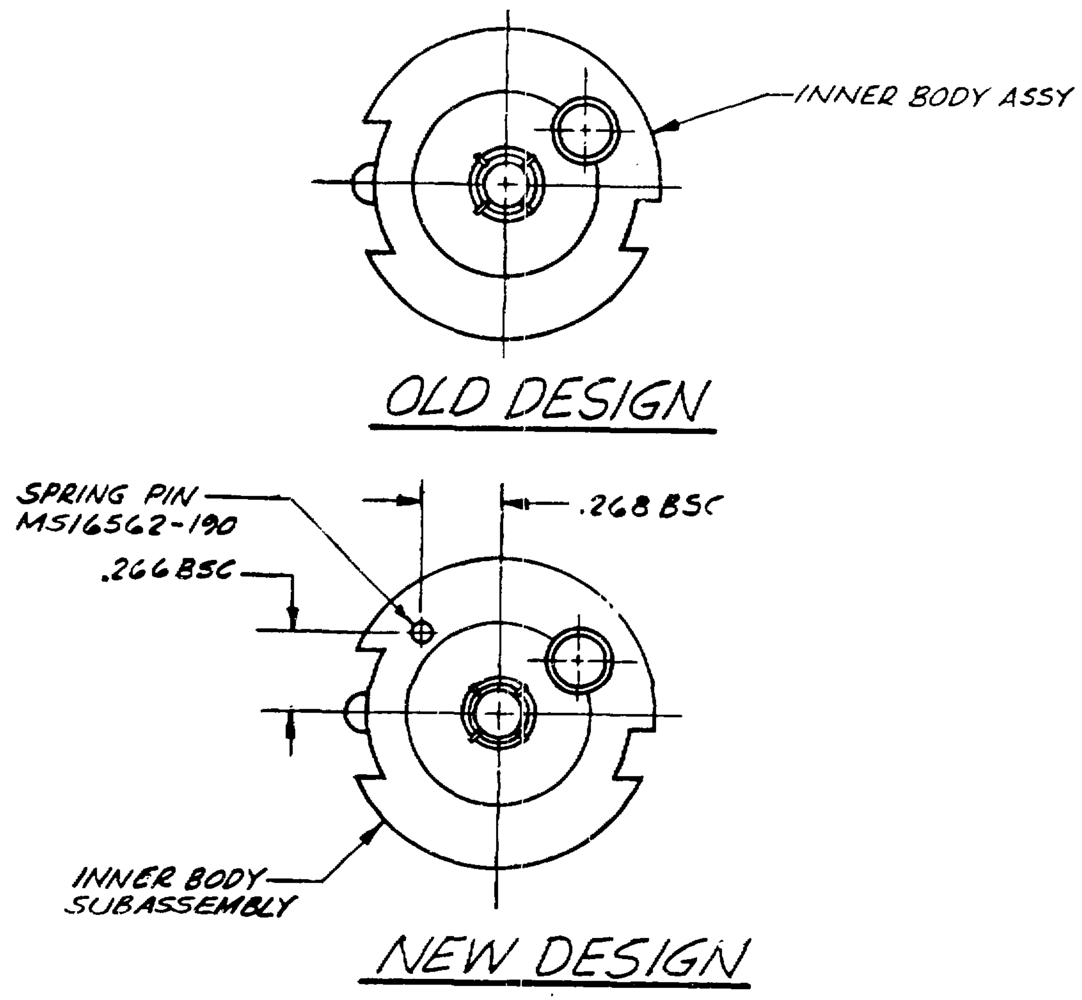


Fig 40 Inner body assembly

APPENDIX A

DEVELOPMENT OF THE M567/XM935 FUZE

The M567 fuze stems from a design acquired from the Netherlands under a Data Exchange Agreement in the late 1950's. Because of the need to clarify some legal questions regarding third party usage, and interrupted funding, development proceeded at a slow rate until 1968 when it was expedited at the request of the Product Manager for Mortars. This request resulted from the difficulty being experienced in producing the M524 and M525 fuzes.

Development work on the M567 was initiated by the Netherlands under MWDP-12-A60, 1 December 1959, U. S. development work continued from August 1963 until the suspension of the work by U. S. Army Materiel Command (AMC) in June 1965. The United States and the Netherlands signed a formal agreement in March 1967, and the development work on the M567 resumed in the U. S. in May 1967. Early in 1968, the AMC Product Manager cited the need for a low-cost mass-producible fuze for the 81 mm mortar. As a result, the U. S. Army Munitions Command (USAMUCOM) directed the completion of the M567 fuze to replace the M524A5 fuze.

The M567 was developed against a Small Development Requirement (SDR) which had been prepared for the Near Surface Burst M588 fuze of Harry Diamond Laboratories. The SDR safety requirements for the fuze are shown below:

Bore safe

Parachute delivery

Normal
Malfunctioning

Drop safe

Delayed arming 100 meters

Transit conditions AR 70-38

Premature rate no greater than 1/1,000,000

For the M567, the requirement that all tests be passed without a pull wire was waived. Nonetheless, extensive testing was done during the Engineering Development phase to show the safety of the fuze without the pull wire in various rough-handling environments. It was also demonstrated that prematurely armed fuzes could be safely fired at top charge in the mortar. The Test and Evaluation Command (TECOM) Firing Record clearly and correctly stated that the mere fact that the fuze was armed did

not, in itself, result in a hazardous condition were the round to be fired; some other failure would also be required for the round to detonate. Table 1 shows the results of the TECOM Engineering Tests/Service Tests (ET/ST) which are now called Development Tests/Operational Tests (DT/OT).

Table 1

Safety tests conducted in DT/OT II

Test (with pull wires in place)	Quantity
7 Day T-H cycle, CH 9 145°F	50
Transportation-vibration 145°F	48
7 Day cold soak	25
Transportation-vibration -65°F	24
Sequential rough handling	48
Adverse conditions	54
Low-velocity air drop	49
High velocity air drop	39
Malfunction parachute	43
Minimum arming distance	300

Despite the large number of tests conducted by the developer without pull wire, TECOM tested the fuzes with pull wires in place and the fuze was declared satisfactory for Army use on the basis that it did have a pull wire. The AMC Type Classification action approving the results of the In Process Review (IPR), which included the TECOM report, merely stated that the fuze was safe for Army use. The safety statement in the TECOM Report Development Acceptance IPR (Deva IPR) indicated that at least 99% assurance at the 95% confidence level was demonstrated that the fuze meets the minimum arming requirement and that the fuze meets all safety requirements after exposure to the extreme temperature storage and rough handling tests.

Subsequent to Type Classification, a Production Engineering Program was conducted at Honeywell to substantially lower the cost of the fuze. Upon completion the ET/ST program was repeated successfully by the developer rather than by an independent agency. Even in retrospect, this does not appear to have been a significant factor.

A production contract for 300,000 fuzes was then awarded to Bulova on the basis of a competitive solicitation. Prior to delivery of the first fuzes, a second contract for an additional 1,000,000 fuzes was placed with Bulova. During lot acceptance testing of the initial quantity a fuze fired while undergoing a Jolt Test at Lone Star Army Ammunition Plant. Production at Bulova was suspended at a cost of approximately $2500 per day for down time. An engineering program was undertaken which had as a major objective restoring Bulova to full production of satisfactory fuzes as rapidly as possible. An Engineering Change Proposal (ECP) was prepared at Picatinny and forwarded to Headquarters, USARMCOM in October 1974. After the normal internal reviews, it was approved by the ARMCOM Configuration Control Board in November 1974, and in March 1975 Bulova was directed to resume production.

The ECP made mandatory with obsclescence a change in the pull wires and made additional changes mandatory without obsolescence. One of these, an improved delay holder, (see Fig 38) was scheduled into production prior to completion of Bulova's second contract even though some existing parts would have to be scrapped. These parts, which necessitated new casting dies, became available in quantity in October 1975 and entered Bulova's production "pipeline" at the component level on November 3, 1975. Since this pipeline was approximately 3 weeks long, no finished fuzes containing the improved delay holder had been produced by Bulova at the time the contract was terminated on 13 November except for a relatively small number of engineering samples.

Meanwhile, a 60 mm version of the M567, XM935, was provided to the Light Weight Company Mortar (LWCM) program to support weapon development. In view of the high cost and the relative unavailability of the XM734 multi-option fuze (MOF), it was planned to conduct a large portion of the DT/OT-II of the weapon and its ammunition with XM935 fuzes. Unfortunately, the fuzes which had been supplied to the LWCM program contained the original pull wire which had never been replaced.

In September 1975, a premature occurred during the sequential rough handling test of 160 rounds of 60 mm ammunition at Aberdeen. Since the rounds involved had not been x-rayed prior to firing, the cause of the malfunction could not be determined with absolute certainty. The subsequent investigation indicated that a fuze failure was the most likely cause.

APPENDIX B

JOLT TESTING

GENERAL

Criteria

It is not required that the fuzes be operable after the test. The criteria by which the samples are judged to have withstood this test are that (1) no elements shall explode and (2) no parts shall be broken, be deformed, be displaced, come apart, or arm in such a manner as to make the assembly unsafe to handle or dangerous to use as determined by examination. Breakdown and inspection, together with engineering judgment, are usually the basis for the decision.

Purpose

The jolt test is used during development and production of fuzes to check the safety and ruggedness of the fuze design.

Description of Test

This test shall consist of jolting each sample fuze 1750 times in each of three positions in the jolt testing machine as shown on Ordnance Corps Drawing 81-3-30. In that part of the test where the fuzes are positioned with the longitudinal axis in a horizontal direction, the fuzes shall be oriented so as to expose what are considered to be the most vulnerable plane(s) of weakness. If used as a development test, it should be repeated at least once or to a point of serious damage to the fuzes. All fuze explosive elements shall be in place during the test.

Results

Table 1 shows results.

Table 1

Tests to failure: Jolt tests

Configurations		Tight in holder (500 G)				Loose in holder (1200 G)
Firing pin: old				×		×
new, one-piece alum					×	
Delay holder: no ribs (old)		×		×		×
ribbed (new)			×		×	
Long pull wire						×
Orientation	**No. of jolts**					
All three/MIL-STD	1,750 ea	0/33[a]	0/33	0/33	0/33	0/95
Horizontal only	14,200	1/11				
Horizontal only	16,000				1/11	
Horizontal only	17,500			0/11		
Horizontal only	36,000				0/11	

[a]No. of failures/no. of fuzes tested.

M525 TESTS

A total of 36 M525 PD fuzes, with pull wires but with safety wires removed, were subjected to the MIL-STD-331 Jolt Test on October 2, 1975. The fuzes were from Lot PA 1-3; the head assemblies, Lot BWC 11-1. Body assemblies were subsequently inspected for safety pin retention, and head assemblies were inspected for firing pin retraction. No evidence of damage was found nor were any of the safety features defective.

M567/XM935 TESTS

Objective

To determine how far the slider moves in a normal jolt test, when it first moves, and which elements of the fuze are the weak links which allow the movement.

Procedure

Fuzes for this test were Bulova Lot 2-2 which was already available at Picatinny. This lot contained hardware of the original production-engineered fuze with the exception of the long pull wire. The pull wire was removed from the fuzes prior to testing.

A flat surface was machined on the XM935 front outer body, parallel to the existing flat for the selector cap, exposing the slider cavity. The depth from this flat to the slider was measured and recorded prior to testing.

The first group of 11 fuzes was attached to the jolt arms in the horizontal position with the selector cap up. Although these fuzes were to be tested one cycle (1750 jolts) in this position, one fuze functioned at 1650 jolts. Examination of the jolt machine and test hardware showed this fuze and five additional fuzes to be loose on their jolt arms. These six test items were removed from the test. These fuzes experienced an extremely high "G" shock for an undetermined length of time so the test was considered nonvalid. The five remaining fuzes were measured for movement after one cycle. The five sliders moved between 0.003 and 0.011 inch, averaging 0.0074 inch. Since all five fuzes had made a significant movement in their first jolt cycle, the next sample would be measured after 100 jolts.

Two fuzes from the first test sample (Number 10, slider movement 0.011 inch, and Number 11, slider movement 0.005 inch) remained on the jolt machine for additional testing. Nine new fuzes were installed on the jolt arms in the same orientation and subjected to 100 jolts before measurement. All nine fuzes showed slider movement between 0.002 and 0.021 inch with 0.005 inch average movement. All measurements of slider positions are recorded in Table 1. The test was concluded when the slider on fuze no. 16 was observed to be in line with the booster lead.

Conclusions

The slider of the M546/XM935 production engineered fuze without improvements is capable of moving a significant distance in one jolt cycle. The average observed movement was 0.014 inch with a maximum 0.063 inch movement.

The slider of the M567/XM935 production engineered fuze without improvements is capable of moving a significant distance in the first 100 jolts of the jolt cycle. The average observed movement was 0.009 inch with a maximum 0.021 inch movement.

The principle causes of slider movement were (1) movement of the right half inner body from the left half inner body, (2) movement of the delay element holder from the left half inner body and, (3) bending of the firing pin point after the slider has moved a distance large enough to rest on the firing pin.

There is a correlation between slider movement and body movement (see Table 1). The hardware damage observed in the jolt testing varied from damage observed in drop testing.

Recommendations

Obtain funds to repeat test on hardware with the following improvements incorporated into the M567/XM935 fuzes: (1) front body spacer with six stronger dimples, (2) delay element holders with ribs, (3) steel tip firing pins.

Table 1a

M567/XM935 jolt-test measurements

No. of jolts \ Fuze no.	12	13	14	15	16	17	18	19	20
	Slider position (inches)								
0[a]	0.450	0.460	0.450	0.415	0.440	0.450	0.450	0.446	0.451
100	0.446	0.445	0.446	0.411	0.415	0.448	0.447	0.427	0.444
200	0.436	0.445	0.445	0.411	0.412	0.448	0.447	0.426	0.439
300	0.436[b]	0.444	0.445	0.410	0.410	0.448	0.446	0.426	0.43[illegible]
1,000		0.440	0.445	0.410	0.378	0.447	0.443	0.424	0.438
2,000		0.438	0.444	0.410	0.377	0.447	0.441	0.422	0.438
3,000		0.432	0.443	0.410	0.310	0.446	0.440	0.420	0.437
4,000		0.406	0.441	0.409	0.365	0.446	0.440	0.418	0.437
6,000		0.373	0.438	0.408	0.362	0.444	0.440	0.407	0.437
8,000		0.368	0.434	0.407	0.358[c]	0.443	0.440	0.403	0.436
12,000		0.364	0.429	0.404		0.439	0.439	0.390	0.431
18,000		0.357	0.426	0.399		0.436	0.434	0.365	0.412
	Total slider movement (inches)								
		0.103	0.024	0.016		0.014	0.016	0.081	0.039
	Inner body separation (inches)								
		0.012	d	d	0.012	d	d	0.010	0.012

[a]Initial reading

[b]Removed from test (loose at about 600 jolts)

[c]Slider shank broken (armed)

[d]Too small to measure in the fuze

Table 1b

M567/XM935 jolt-test measurements

Fuze no.	7	8	9	10	11
No. of jolts	Slider position (inches)				
0[a]	0.433	0.438	0.446	0.448	0.448
1,750	0.430[b]	0.427[b]	0.439[b]	0.437	0.443
1,850				0.435	0.442
1,950				0.435	0.442
2,050				0.435	0.442
2,750				0.433	0.442
3,750				0.428	0.442
4,750				0.426	0.442
5,750				0.421	0.442
7,750				0.413	0.442
9,750				0.404	0.442
13,750				0.380	0.442
19,750				0.383	0.440
	Total movement (inches)				
				0.065	0.008
	Inner body separation (inches)				
				0.012	[c]

[a]Initial reading

[b]Removed from test

[c]Too small to measure in the fuze

ENGINEER: M. Della Terza LAB: AD&ED, FEB, Mortar Section

REVIEWED BY: ______________ DATE: 9 October 1975

ITEM: Fuze, PD, M567/M935 TEST NO.: 005

TEST OBJECTIVE:

The objective of this test is to discover if Bulova's current M567 production represented by BWV 07-75-2-2 can pass repetitive jolt tests in the most detremental orientation (selector cap up, fuzes mounted horizontally on the jolt arms) without pullwire assemblies.

CONCLUIONS AND RECOMMENDATIONS:

1. As long as the front body assembly and the rear body remain tight to each other and the jolt arm, Bulova's current production which represents all Bulova's production to date can successfully pass a severe jolt test.

2. The higher than normal "g" loads which occur when the front or rear body loosens on the jolt arm will cause the slider to move into the armed position.

3. Recommend that a torque wrench procedure be utilized for tightening the rear body to the jolt arm during production acceptance testing at Lone Star AAP. Picatinny should develop the required torque values.

BACKGROUND:

This testing is part of the M567/M935 malfunction program.

DESCRIPTION OF MATERIAL:

1. Fuze Front Body Assemblies, BWV 07-75-2-2, without Lead Assembly and Pullwire Assembly.

2. Empty Rear Bodies.

3. Shims of various sizes to orent selector caps.

TEST #005 - REPETITIVE JOLT TEST - FUZE, PD, M567 - BWV 07-75-2-2

(PULLWIRES REMOVED, REAR BODIES USED ON JOLT ARMS)

JOLT ARM #	1	2	3	4	5	6	7	8	9	10	11
FUZE #	AA	BB	CC	DD	EE	FF	GG	HH	II	JJ	KK
1st Jolt -Fuzes in top position	ALL FUZES WERE TIGHT AT END OF TEST										
2nd Jolt -Fuzes in horizontal position (selector cap & shim thickness given)	11 o'clock .1 cm	12 o'clock .1 cm	12 o'clock 1.1 cm	11 o'clock .1 cm	12 o'clock .1 cm Front body loose, det in line, removed from test.	11.5 o'clock .1 cm	12.5 o'clock .4 cm	12.5 o'clock .2 cm	12.5 o'clock .3 cm	12.5 o'clock .3 cm	12 o'clock .1 cm
3rd Jolt -Fuzes in bottom position	ALL FUZES TIGHT										
4th Jolt -Fuzes in Horiz position (Selector cap position & shim thickness same as 2nd Jolt.	ALL FUZES TIGHT										
5th Jolt - Fuze in Horiz Position	ALL FUZES TIGHT										
6th Jolt -Fuzes in Horiz Position	ALL FUZES TIGHT										
7th Jolt -Fuzes in Horiz Position	ALL FUZES TIGHT										
8th Jolt -Fuzes in Horiz Position	ALL FUZES TIGHT										
9th Jolt -Fuzes in Horiz Posution	ALL FUZES TIGHT										

TEST #005 - REPETITIVE JOLT TEST - FUZE, PD, M567 - BWV 07-75-2-2

(PULLWIRES REMOVED, REAR BODIES USED ON JOLT ARMS)

(Continued)

10th Jolt - Fuzes in Horiz Position	ALL FUZES TIGHT
11th Jolt - Fuzes in Horiz Position (Test stopped at 1450th Jolt)	ALL FUZES TIGHT - NO SLIDER MOVEMENT IN ANY FUZE.

DISCUSSION OF RESULTS:

The fuzes being tested are those which Bulova is currently assembling and are representative of Bulova's M567 production to date. The severe jolt test results indicate that the M567 fuzes will not arm, even without the pullwire assembly, as long as the front body assembly is tight to the rear body and the rear body is tight to the jolt arm. If any looseness occurs, then the fuze will arm sometime during the jolt cycle that it is experiencing.

Lone Star AAP which conducts the M567 production acceptance jolt test has had an M567 explosion on the jolt machine. It will be necessary in the future when production again begins to fully quarantee, either by redesigning the jolt fixture or by establishing torque requirements, that the front and rear bodies are always prevented from loosening.

TEST PROCEDURE:

Eleven (11) M567 Fuzes without lead assemblies and pullwire assemblies and with empty rear bodies were first subjected to 1750 jolts in the top jolt arm position. Next, the eleven (11) fuzes were assembled in the horizontal position using shims to orient the selector caps to approximately 12 o'clock. Shim thicknesses and selector cap orientations were recorded, then the fuzes were subjected to a complete jolt cycle. The fuzes were then removed from the horizontal position and jolted. Finally, the eleven (11) fuzes were returned to the horizontal position, oriented and shimed, then given seven (7) complete jolt cycles. The test was discontinued at the 1450th jolt of the eighth horizontal cycle.

SUMMARY OF RESULTS:

REPETITIVE JOLT TEST OF FUZE, PD, M567 (BWV 07-75-2-2)

a. 1 Fuze armed during the first horizontal jolt cycle because the front body assembly became loose.

b. 0/10 fuzes armed at completion of testing.

Engineer: M. Della Terza	Lab: AD&ED, FEB, MORTAR SECTION
Review By:	Date: 6th October 1975
Item: Fuze, PD, M567/M935	Test No: 006

Test Objective:

The objective of this test is to discover if Bulova's special M567 production manufactured according to Contract DAAA21-76-C-0059 utilizing the six-nibbed Front Body Spacer, dwg. 9246254 REV B, and the ribbed Delay Holder, dwg. 9246247 REV E, could successfully pass, without Pull Wire Assembly and with the Firing Pin tip ground off, a MIL-STD Jolt Test.

Conclusions and Recommendations:

1. The special Bulova M567 Fuze production, utilizing the six-nibbed spacer and the ribbed Delay Holder with the Firing Pin and Pull Wire safety systems subveried, will successfully pass the MIL-STD Jolt Test.

2. When the Front Body Assembly becomes loose, there is appreciably more damage to the arming pin detent surface on the Slider End Plate.

3. Recommend that a torque wrench requirement for the Rear Body to the jolt arm be developed and the present torque requirement of the Front Body Assembly to the Rear Body Assembly be carefully analyzed so that it will be very unlikely that looseness will ever occur during the jolt test or during the M567's life cycle.

Background:

This testing is part of the M567/M935 malfunction program.

Description of Material:

1. Live M567 Front Body Assemblies purchased as special assemblies from Bulova Watch Co. under Contract DAAA21-76-C-0059. These fuzes have the six-nibbed Front Body Spacer, dwg. 9246254 REV D, the ribbed Delay Holder, dwg. 9246247 REV E, and ground-off Firing Pin tips. The Lead Assemblies were removed before testing.

2. The Rear Bodies were empty.

3. Shims of various sizes to orient the Selector Cap in the "UP" position for horizontal jolt.

DATA:

Test #006 - MIL-STD Jolt Test
Fuze, PD, M567 - (Pull wires removed and firing pin tip ground off, six nibbed Front Body Spacer and ribbed Delay Holder)

1ST JOLT CYCLE

Jolt Arm #	1	2	3	4
Top Position	Fuze #122	150	151	124
Horizontal (Selector Cap Position and Shim Thickness)	132 (10'clock, .3cm)	181 (11.5 o'clock .2cm)	172 (11 o'clock, .9cm) (Front Body Loose)	154 (11 o'clock, .2cm)
Bottom	109	130	187	152 (Front Body Loose)

Jolt Arm #	5	6	7	8
Top Position	197	163	170	196
Horizontal	116 (11.0, .2)	192 (12.5, .6)	193 (11.0, .5)	162 (1.0, .4)
Bottom	174	200	191	171

Jolt Arm #	9	10	11
Top Position	190	136	178
Horizontal	195 (1.0, .2)	127 (11.5, .4) (Front Body Loose)	159 (12.5, .6)
Bottom	164	173	160

2ND JOLT CYCLE

Jolt Arm #	1	2	3	4
Top Position	109	130	187	152
Horizontal	122 (12.5, 1.0) (Front Body Loose)	150 (11.5, .6)	151 (12.5, .4)	124 (12.0, .4)
Bottom	132	181	172	154

Jolt Arm #	9	10	11
Top Position	164	173	160
Horizontal	190 (1.0, .05)	136 (12.0, .1)	178 (11.0, 1.1)
Bottom	195	127 (Front Body Loose)	159

3RD JOLT CYCLE

Jolt Arm #	1	2	3	4
Top Position	132	181	172	154
Horizontal	109 (12.5, .3)	130 (12.5, .5)	187 (1.0, 1.1)	152 (12.5, .7)
Bottom	122	150	151	124

Jolt Arm #	5	6	7	8
Top Position	116	192	193	162
Horizontal	174 (12.0, 1.2)	200 (12.0, 1.2)	191 (12.0, .3)	171 (1.0, .2)
Bottom	197	163	170	196

3RD JOLT CYCLE
(Cont'd)

Jolt Arm #	9	10	11
Top Position	195	127 (Front Body Loose)	159
Horizontal	164 (11.0, .5)	173 (12.0, .6)	160 (12.0, .8)
Bottom	190	136	178

Discussion of Results:

This test is a retest of one for which there was a high incidence of loose Front Body Assemblies. It was decided to apply RTV selant in the Front-Rear Body thread and permit it to set for a period of time (43 hours) and to carefully tighten the Rear Body to the jolt arm before conducting this test. Even with all these precautions, some Front Body assemblies were noted in the data as being loose at the completion of a jolt cycle.

Test Procedure:

Thirty-three modified M567 Fuzes were subjected to the MIL-STD Jolt Test after RTV sealant applied to the Front-Rear Body thread surface was allowed to cure approximately 43 hours.

All horizontal positioned fuzes were oriented with the Selector Cap as close to the 12 o'clock position as possible by shimming.

After each of the three cycles, the looseness of the Front Body Assembly or Rear Body was noted and any loose fuze retightened as the fuze was placed in its next position. Upon test completion, the fuzes were sent to Bldg. 617 for teardown.

Summary of Results:

Test #006 - MIL-STD Jolt Test of Fuze, PD, M567 (Pull wires removed, Firing Pin tips ground off, six nibbed Front Body Spacer, and ribbed Delay Holder)

1. No fuzes were armed out of the thirty-three subjected to this test.

2. Eight fuzes had Front Body Assemblies which were slightly loosened during the Jolt cycles causing partial slider movement.

JOLT TEST DATA

JOLT TEST - XM935 Fuze - R. Stone, Date of Test: 1 - 11 Nov 75

GROUP III - New Delay Holders (Ribbed); New Firing Pins; New Spacer Plate

Test Plan:

1. Standard Jolt Test (MIL-STD-331) - Leather pads on wood Impact blocks.

   33 Fuzes placed on 11 arms of jolt machine; 3 positions, each arm:

   a. Base Down

   b. Horizontal, Selector Cap Up.

   c. Nose Down.

2. Then test 11 fuzes from above group to failure: Horizontal, selector cap up. Inspect at every 100 jolts at first, working up to inspection at every 1000 jolts.

RESULTS:

1. Standard Jolt Test: None of the fuzes armed, no portion of detonator visible.

2. Test to Failure (11 Fuzes).

   A. One fuze exhibited partial arming (3/32 inch of detonator visible through booster lead hole) at inspection after 3600 jolts (plus standard jolt test). This fuze had loosened on its arm during the standard jolt test.

   B. Two fuzes plus fuze mentioned above removed from testing after 11,600 jolts (plus Standard Jolt Test). All 3 fuzes torn down for inspection. Only the first fuze (mentioned above) exhibited sufficient slider movement to expose a portion of the detonator.

C. The remaining fuzes were jolted so that they received a total of 30,200 jolts (plus Standard Jolt Test). None of these fuzes were found with any portion of the detonator visible through the Booster Lead Hole.

APPENDIX C

DROP TESTING

DROP TESTING

Criteria

1. After a single drop from 5 feet, the bare fuze must be safe to fire; the packaged fuze must be safe and operable.

2. After a single drop from between 5 and 40 feet, either bare or packaged, the fuze must be safe to handle and dispose.

3. There were no requirements applicable to drops of more than 40 feet; these drops were for information only.

Results

With pull wires and all safeties in place, all fuzes met the requirements of MIL-STD-331 for 5- and 40-foot bare drops and for packaged drops. Table 1 gives results and Figure 1 shows the relative standings of various M567, M524 and M525 configurations with their respective cumulative probability of arming at a given drop height.

In a test-to-failure of production XM935 fuzes with long pull wires (using the 60 mm package and worst orientation), two boxes (32 fuzes) were dropped from 80 feet, and one box (16 fuzes) was dropped from 100 feet. None of the fuzes armed.

ONE-SHOT TRANSFORMED RESPONSE (OSTR) TEST PLAN

A statistically designed test plan was proposed for determining fuze sensitivity to arm when dropped. Since interest was focused on the minimum drop height which would cause the fuze to arm, a One shot Transformed Response test strategy for extreme percentage points[1] was proposed and implemented. This plan was designed to determine the minimum drop height which would cause the slider to move into an armed position. A one shot test strategy with No. = 6 was recommended. This strategy afforded a method of examining the lower (in this case, the low drop height) tail performance of the response distribution. Also, an No. = 6 afforded an efficient method of examining fuze sensitivity to arm, after

[1] S. K. Einbinder, "One Shot Sensitivity Test for Extreme Percentage Points," Proceedings of the Nineteenth Conference on the Design of Experiments in Army Research and Development Testing, ARO Report 74-1, 1974, pp 369-386

Table 1

Tests to failure: Bare drop tests

(Ambient temperature and worst orientation, selector in vertical plane)

Configurations						
Firing pin: old	x	x				
new, one-piece alum					x	x
Delay holder: no ribs (old)	x	x				
ribbed (new)			x	x	x	x
Long pull wire	x			x		x
Drop heights (feet						
Minimum observed for arming	15[a]	10.3			100	100
20			0/5[b]			
30			0/5			
40				0/20		
50	1/6					
100					2/22	2/50

[a]Slider armed after pull wire withdrawn.

[b]No. of fuzes armed/no. of fuzes dropped.

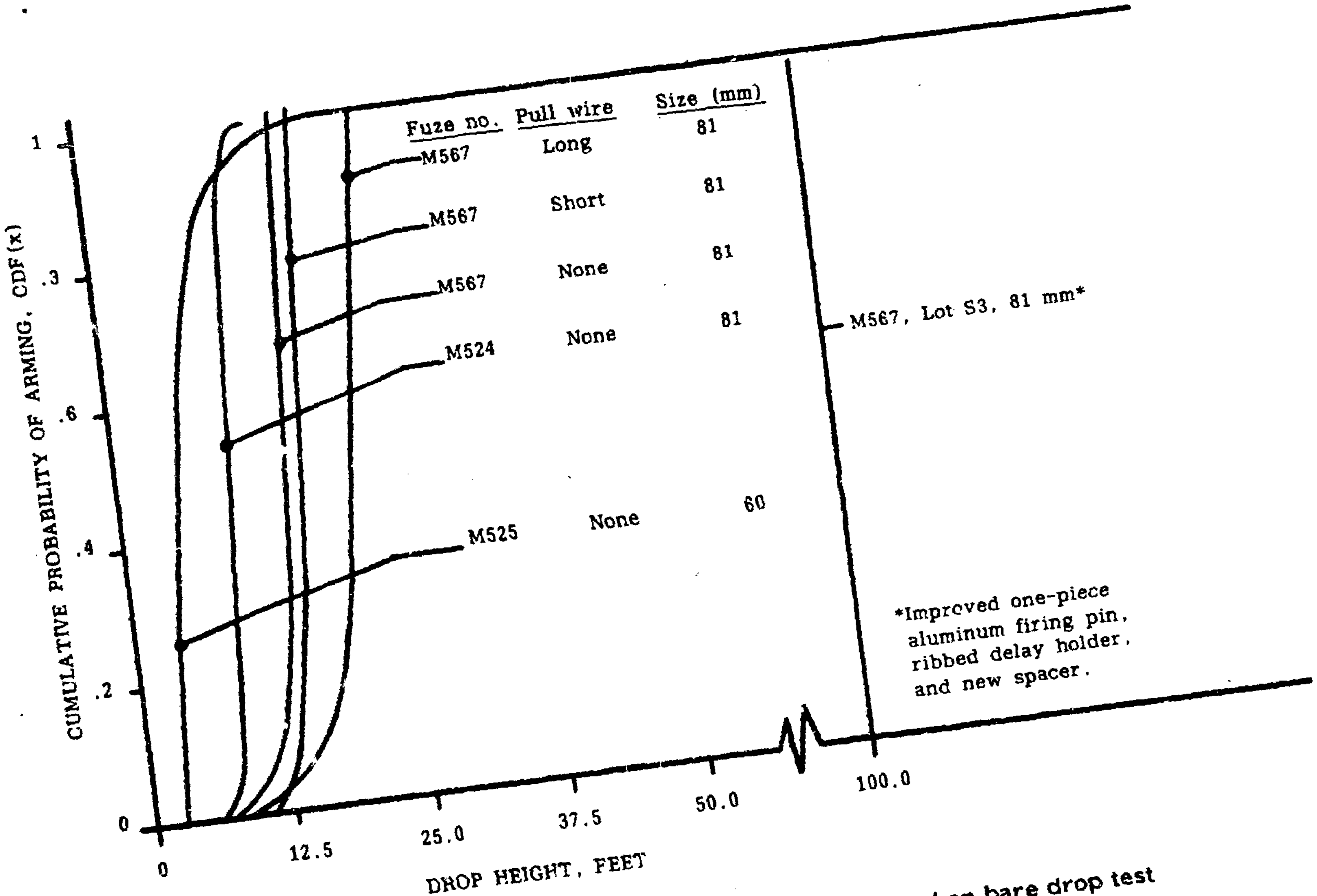


Fig 1 Probability distribution of empirical test data based on bare drop test

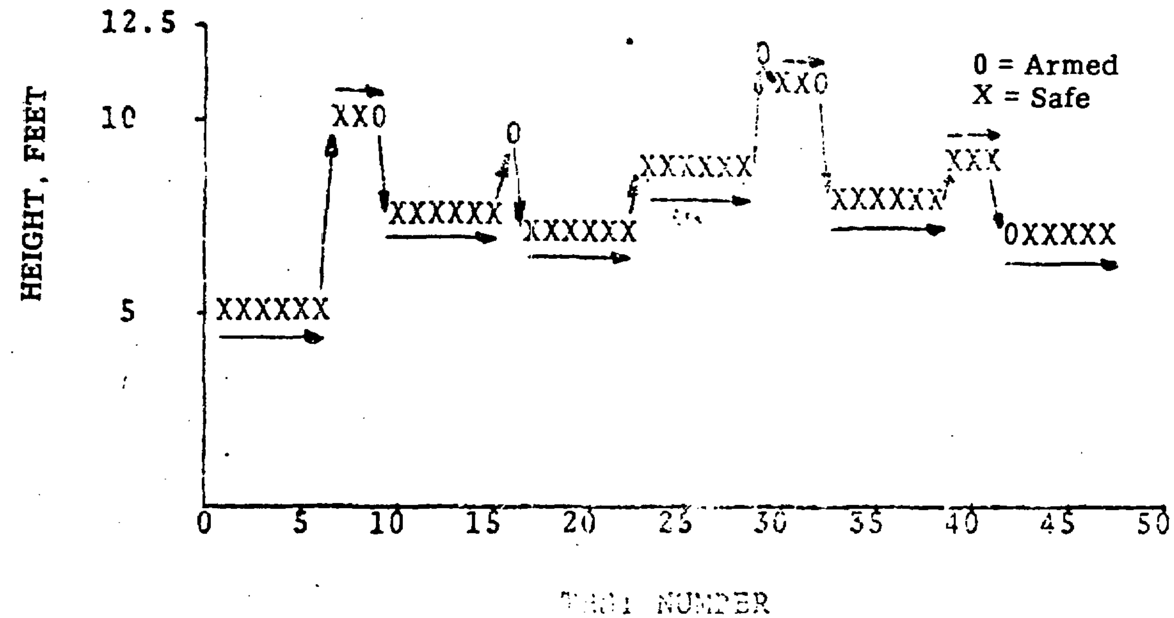


Fig 2 Plot of Langley drop test data (Test 2)

drop, within the restrictive limits of hardware and time. It was anticipated that 50 fuzes of each type would be required. The No = 6 defines the transformation which determines the response quantile around which the test levels tend to concentrate. This quantile is called the transformed median percentage (TMP). For No = 6, the TMP = 10.92%[2]. The response distribution is designed to make a decrease in stress (in this case, drop) easier than an increase, denoted by a 0 and a negative response by a 1. A positive response is a type U response, which requires an increase in stress level, is allowed to occur after No confirmations of a positive response. In this case a type U response consisted of a (000000) outcome and a type D response of the set of outcomes (1), (01), (001), (0001), (00001) or (000001). Lower and upper stress limits (in this case, drop) were chosen in advance of the test. The lower limit represented the drop at which fuze arming was expected not to occur, while the upper limit was chosen to be the drop at which fuze arming would be expected to occur 100% of the time.

During the progress of the test program four different fuze designs for the M567 fuze were subject to test. These designs represented the following types, with short pullwire, with long pullwire, without pullwire and one type, designated lot S3, without pullwire. Also, during the progress of the tests of the design with the long pullwire, it was noted by the test engineer that the changes in fuze orientations upon impact from the high drop heights (25 to 50 feet) were greater than when the fuzes were dropped from heights of 20 feet or lower. Therefore, in the statistical analysis of the empirical data for this design only, responses obtained from drops made between 25 feet and 50 feet were excluded from the analysis.

Analysis of Test Data

Empirical data, Inclosures 1 through 6, were subjected to statistical analysis assuming a Weibull mathematical model. A computer program[3] was employed to assist in the analysis of the test data. The program uses maximum likelihood theory to derive both standard and reflected forms of the Weibull distribution, point and confidence estimates of the parameters, and point and interval estimates of the reliability and percentage points. Working in conjunction with the computer program and the test data requires considerable experience in determining the best set of Weibull parameters. Estimation of the best set of parameters requires flexibility and capability in fitting the best response functions to experimental outcomes in the local stress region of interest.

[2] Ibid p. 378
[3] Ibid p. 386

The results of statistical analysis assuming a Weibull model are listed below showing the maximum likelihood estimates of the three Weibull parameters together with the form of the Weibull used.

Fuze Design	γ	θ	α	Weibull form[4]
M524	15.0	5.18542	3.47100	Reflected
M525	2.6	3.95922	1.05155	Standard
M567 short pull wire	20.0	4.09857	1.91250	Reflected
M567 long pull wire	25.0	4.48857	1.22704	Reflected
M547 without pull wire	17.5	2.73209	1.16468	Reflected
M567 Lot S3 without pull wire	101.0	1.07285	5.30831	Reflected

[4]The following apply:

The standard Weibull density function is

$$f(x) = \frac{\alpha(x-\gamma)^{\alpha-1}}{\theta^{\alpha}} \; e^{-\left(\frac{x-\gamma}{\theta}\right)^{\alpha}}$$

The standard Weibull probability function is

$$F(x) = 1 - e^{-\left(\frac{x-\gamma}{\theta}\right)^{\alpha}}$$

The reflected Weibull density function is

$$f(x) = \frac{\alpha(\gamma-x)^{\alpha-1}}{\theta^{\alpha}} \; e^{-\left(\frac{\gamma-x}{\theta}\right)^{\alpha}}$$

The reflected Weibull probability function is

$$F(x) = e^{-\left(\frac{\gamma-x}{\theta}\right)^{\alpha}}$$

M567 81mm with Long Pullwire

Horizontal, Selector Cap Up

28 Oct 1975

TRIAL	STRESS X(I)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
1	50	0		
2	50	0		
3	50	0		
4	50	1	D	
5	50	1	D	
6	50	0		
7	40	0		
8	40	0		
9	40	0		
10	40	0		
11	40	0		
12	40	1	D	
13	35	0		
14	35	0		
15	35	0		
16	35	1	D	
17	30	0		
18	30	0		
19	30	0		
20	30	1	D	
21	25	0		
22	25	1	D	
23	20	0		
24	20	0		
25	20	0		
26	20	0		
27	20	1	D	
28	15	0		
29	15	0		
30	15	1	D	
31	10	0		
32	10	0		
33	10	0		
34	10	0		
35	10	0		
36	10	0		1
37	12.5	0		
38	12.5	0		
39	12.5	0		
40	12.5	0		

M567 w/Long Pullwire Horizontal, Selector Cap Up (Cont.)

TRIAL	STRESS X(I)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
41	12.5	0		
42	12.5	0	U	
43	18.75	0		
44	18.75	1	D	2
45	15.62	0		
46	15.62	0		
47	15.62	0		
48	15.62	0		
49	15.62	0		
50	15.62	0	U	3

U = 000000
D = 000001, 00001, 0001, 001, 01, 1

0 = Non-arm

1 = Arm

M567 81mm with Short Pullwire

Horizontal, Selector Cap Up

24 Oct 1975

TRIAL	STRESS X(I)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
1	6	0		
2	6	0		
3	6	0		
4	6	0		
5	6	0		
6	6	0	U	
7	11	0		
8	11	0		
9	11	0		
10	11	0		
11	11	0		
12	11	0	U	
13	13.5	0		
14	13.5	0		
15	13.5	0		
16	13.5	0		
17	13.5	0		
18	13.5	0	U	
19	14.75	0		
20	14.75	0		
21	14.75	0		
22	14.75	0		
23	14.75	1	D	1
24	14.12	0		
25	14.12	0		
26	14.12	0		
27	14.12	0		
28	14.12	1	D	
29	12.56	0		
30	12.56	1	D	
31	9.28	0		
32	9.28	0		
33	9.28	0		
34	9.28	0		
35	9.28	0		
36	9.28	0	U	2
37	11.42	0		
38	11.42	0		
39	11.42	0		
40	11.42	0		

M567 81mm with Short Pullwire Horizontal Selector Cap Up (Cont.)

TRIAL	STRESS X(I)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
41	11.42	0		
42	11.42	0	U	
43	12.77	0		
44	12.77	0		
45	12.77	0		
46	12.77	0		
47	12.77	0		
48	12.77	0	U	
49	13.76	0		
50	13.76	0		

U = 000000

D = 000001, 00001, 0001, 001, 01, 1

0 = Non-arm

1 = Arm

M567 81mm without Pullwire

Horizontal, Selector Cap Up

23 Oct. 1975

TRIAL	STRESS X(I)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
1	50	0		
2	50	1	D	
3	30	0		
4	30	1	D	
5	20	0		
6	20	1	D	
7	15	1	D	
8	10	0		
9	10	0		
10	10	0		
11	10	0		
12	10	0		
13	10	0	U	1
14	12.5	0		
15	12.5	0		
16	12.5	0		
17	12.5	0		
18	12.5	0		
19	12.5	1	D	2
20	11.25	0		
21	11.25	0		
22	11.25	0		
23	11.25	0		
24	11.25	0		
25	11.25	0	U	3
26	11.87	0		
27	11.87	0		
28	11.87	0		
29	11.87	0		
30	11.87	0		
31	11.87	0	U	
32	15.94	0		
33	15.94	1	D	4
34	13.91	0		
35	13.91	0		
36	13.91	0		
37	13.91	0		
38	13.91	0		
39	13.91	1	D	
40	12.58	0		

M567 81mm Without Pullwire Horizontal, Selector Cap Up (Cont.)

TRIAL	STRESS X(U)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
41	12.58	0		
42	12.58	0		
43	12.58	1	D	
44	10.29	0		
45	10.29	0		
46	10.29	0		
47	10.29	0		
48	10.29	1	D	
49	9.14	0		
50	9.14	0		

U = 000000

D = 000001, 00001, 0001, 001, 01, 1

0 = Non-arm

1 = Arm

M524 81mm

16 Oct 1975

TRIAL	STRESS X(I)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
1	5.00	0		
2	5.00	0		
3	5.00	0		
4	5.00	0		
5	5.00	0		
6	5.00	0	U	
7	10.00	0		
8	10.00	0		
9	10.00	1	D	1
10	7.50	0		
11	7.50	0		
12	7.50	0		
13	7.50	0		
14	7.50	0		
15	7.50	0	U	2
16	8.75	1	D	3
17	6.87	0		
18	6.87	0		
19	6.87	0		
20	6.87	0		
21	6.87	0		
22	6.87	C	U	4
23	8.43	0		
24	8.43	0		
25	8.43	0		
26	8.43	0		
27	8.43	0		
28	8.43	0	U	
29	11.72	1	D	5
30	10.86	0		
31	10.86	0		
32	10.86	1	D	
33	7.93	0		
34	7.93	0		
35	7.93	0		
36	7.93	0		
37	7.93	0		
38	7.93	0	U	6
39	8.96	0		
40	8.96	0		

M524 81mm (Cont.)

TRIAL	STRESS X(I)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
41	8.96	1	D	7
42	6.98	0		
43	6.98	0		
44	6.98	0		
45	6.98	0		
46	6.98	0		
47	6.98	0	U	8
48	8.49	1	D	9
49	6.75	0		
50	6.75	0		

U = 000000

D = 000001, 00001, 0001, 001, 01, 1

0 = Non-arm

1 = Arm

M525 60mm LWCM

17 Oct 1975

TRIAL	STRESS X(I)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
1	5.00	0		
2	5.00	0		
3	5.00	1	D	
4	4.00	0		
5	4.00	1	D	
6	3.50	0		
7	3.50	0		
8	3.50	0		
9	3.50	0		
10	3.50	0		
11	3.50	0	U	1
12	3.75	0		
13	3.75	0		
14	3.75	0		
15	3.75	0		
16	3.75	1	D	2
17	3.62	1	D	
18	3.31	0		
19	3.31	0		
20	3.31	0		
21	3.31	0		
22	3.31	0		
23	3.31	0	U	3
24	3.47	1	D	4
25	3.39	0		
26	3.39	0		
27	3.39	0		
28	3.39	0		
29	3.39	1	D	
30	3.19	0		
31	3.19	0		
32	3.19	0		
33	3.19	0		
34	3.19	0		
35	3.19	0	U	5
36	3.29	1	D	6
37	3.24	0		
38	3.24	0		
39	3.24	0		
40	3.24	0		

Incl. 5

!525 60mm LWCM (Cont.)

'RIAL	STRESS X(I)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
41	3.24	0		
42	3.24	1	D	
43	3.12	0		
44	3.12	0		
45	3.12	0		
46	3.12	0		
47	3.12	0		
48	3.12	1	D	
49	3.06	0		
50	3.06			

U = 000000

D = 000001, 00001, 0001, 001, 01, 1

0 = Non -arm

1 = Arm

M567 81mm Lot S3*

Horizontal, without Pullwire

1 Nov 1975

TRIAL	STRESS X(I)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
1	100	0		
2	100	0		
3	100	0		
4	100	1	D	
5	90	0		
6	90	0		
7	90	0		
8	90	0		
9	90	0		
10	90	0	U	1
11	95	0		
12	95	0		
13	95	0		
14	95	0		
15	95	0		
16	95	0	U	
17	97.5	0		
18	97.5	0		
19	97.5	0		
20	97.5	0		
21	97.5	0		
22	97.5	0	U	
23	98.75	0		
24	98.75	0		
25	98.75	0		
26	98.75			
27	98.75	0		
28	98.75	0	U	
29	99.37	0		
30	99.37	0		
31	99.37	0		
32	99.37	0		
33	99.37	0		
34	99.37	0	U	
35	100	0		
36	100	0		
37	100	0		
38	100	0		
39	100	0		
40	100	0	U	

* FIRST GROUP FROM BULOVA - 1) DIMPLE SPACER PLATE 2) RIB DELAY HOLDER 3) 1 Pce ALUM PI

Incl. 6

M567 81mm Lot S3 Horizontal without Pullwire (Cont.)

TRIAL	STRESS X(I)	RESPONSE Y(I)	RESPONSE TYPE	CHANGE NUMBER
41	100	0		
42	100	0		
43	100	0		
44	100	0		
45	100	0		
46	100	0		
47	100	0		
48	100	0	U	
49	100	1	D	2
50	100	0		

U = 000000

D = 000001, 00001, 0001, 001, 01, 1

0 = Non-arm

1 = Arm

NOTE: To accommodate test data above to statistical analysis, trial #49, stress value X(I) was input as 99.9 in lieu of 100. This was done in order to create an overlap region which is a necessary condition for analysis.

It should be noted, too, that 100 ft. was the limit of the test fixture.

DROP TEST DATA

TABLE #1: MODIFIED LANGLEY DROP TEST DATA

Response: Armed Fuze = 0

Safe Fuze = 1

Stress: Drop Height in Feet

Test 1

Fuze: M525, W/O Pull Wire

Projectile: 60 MM, XM720

Date: 17 October 1975

Orientation: Base Down

Trail	Stress X (I)	Response Y (I)	Response Type*	Change Number*
1	5.00	0		
2	5.00	0		
3	5.00	1	D	
4	4.00	0		
5	4.00	1	D	
6	3.50	0		
7	3.50	0		
8	3.50	0		
9	3.50	0		
10	3.50	0		
11	3.50	0	U	1
12	3.75	0		
13	3.75	0		
14	3.75	0		
15	3.75	0		
16	3.75	1	D	2
17	3.62	1	D	
18	3.31	0		
19	3.31	0		
20	3.31	0		
21	3.31	0		
22	3.31	0		
23	3.31	0	U	3
24	3.47	1	D	4
25	3.39	0		
26	3.39	0		
27	3.39	0		
28	3.39	0		
29	3.39	1	D	
30	3.19	0		
31	3.19	0		
32	3.19	0		

*See OSTR Test Plan

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
33	3.19	0		
34	3.19	0		
35	3.19	0	U	5
36	3.29	1	D	6
37	3.24	0		
38	3.24	0		
39	3.24	0		
40	3.24	0		
41	3.24	0		
42	3.24	1	D	
43	3.12	0		
44	3.12	0		
45	3.12	0		
46	3.12	0		
47	3.12	0		
48	3.12	1	D	
49	3.06	0		
50	3.06	0		

TEST 2

Fuze: M524, W/O Pull Wire

TEST 2 IS SHOWN GRAPHICALLY IN FIG. C-1

Projectile: 81MM, M374

Date: 16 October 1975

Orientation: 10^{o} Horizontal, Base Down, Trigger Down

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	5.00	0		
2	5.00	0		
3	5.00	0		
4	5.00	0		
5	5.00	0		
6	5.00	0	U	
7	10.00	0		
8	10.00	0		
9	10.00	1	D	1
10	7.50	0		
11	7.50	0		
12	7.50	0		
13	7.50	0		
14	7.50	0		
15	7.50	0	U	2
16	8.75	1	D	3
17	6.87	0		
18	6.87	0		
19	6.87	0		
20	6.87	0		
21	6.87	0		
22	6.87	0	U	4
23	8.43	0		
24	8.43	0		

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
25	8.43	0		
26	8.43	0		
27	8.43	0		
28	8.43	0	U	
29	11.72	1	D	5
30	10.86	0		
31	10.86	0		
32	10.86	1	D	
33	7.93	0		
34	7.93	0		
35	7.93	0		
36	7.93	0		
37	7.93	0		
38	7.93	0	U	6
39	8.96	0		
40	8.96	0		
41	8.96	1	D	7
42	6.98	0		
43	6.98	0		
44	6.98	0		
45	6.98	0		
46	6.98	0		
47	6.98	0	U	8
48	8.49	1	D	9
49	6.75	0		
50	6.75	0		

TEST 3

Fuze: M567, W/O Pull Wire

Projectile: 81mm, M374

Date: 23 October 1975

Orientation: Horizontal, Selector Cup Up

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	50	0		
2	50	1	D	
3	30	0		
4	30	1	D	
5	20	0		
6	20	1	D	
7	15	1	D	
8	10	0		
9	10	0		
10	10	0		
11	10	0		
12	10	0		
13	10	0	U	1
14	12.5	0		
15	12.5	0		
16	12.5	0		

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
17	12.5	0		
18	12.5	0		
19	12.5	1	D	2
20	11.25	0		
21	11.25	0		
22	11.25	0		
23	11.25	0		
24	11.25	0		
25	11.25	0	U	3
26	11.87	0		
27	11.87	0		
28	11.87	0		
29	11.87	0		
30	11.87	0		
31	11.87	0	U	
32	15.94	0		
33	15.94	1	D	4
34	13.91	0		
35	13.91	0		
36	13.91	0		
37	13.91	0		
38	13.91	0		
39	13.91	1	D	
40	12.58	0		
41	12.58	0		
42	12.58	0		
43	12.58	1	D	
44	10.29	0		
45	10.29	0		
46	10.29	0		
47	10.29	0		
48	10.29	1	D	
49	9.14	0		
50	9.14	0		

TEST 4

Fuze: M567, W/ **Short pull wire**

Projectile: 81mm, M374

Date: 27 October 1975

Oreintation: Horizontal, Selector Cup Up

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	6	0		
2	6	0		
3	6	0		
4	6	0		
5	6	0		
6	6	0	U	
7	11	0		
8	11	0		

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
9	11	0		
10	11	0		
11	11	0		
12	11	0	U	
13	13.5	0		
14	13.5	0		
15	13.5	0		
16	13.5	0		
17	13.5	0		
18	13.5	0	U	
19	14.75	0		
20	14.75	0		
21	14.75	0		
22	14.75	0		
23	14.75	1	D	1
24	14.12	0		
25	14.12	0		
26	14.12	0		
27	14.12	0		
28	14.12	1	D	
29	12.56	0		
30	12.56	1	D	
31	9.28	0		
32	9.28	0		
33	9.28	0		
34	9.28	0		
35	9.28	0		
36	9.28	0	U	2
37	11.42	0		
38	11.42	0		
39	11.42	0		
40	11.42	0		
41	11.42	0		
42	11.42	0	U	
43	12.77	0		
44	12.77	0		
45	12.77	0		
46	12.77	0		
47	12.77	0		
48	12.77	0	U	
49	13.76	0		
50	13.76	0		

TEST 5

Fuze: M567, W/Long Pull Wire

Projectile: 81mm, M374

Date: 28 October 1975

Oreintation: Horizontal, Selector Cup Up

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	50	0		
2	50	0		
3	50	0		
4	50	1		
5	50	1	D	
6	50	0		
7	40	0		
8	40	0		
9	40	0		
10	40	0		
11	40	0		
12	40	1	D	
13	35	0		
14	35	0		
15	35	0		
16	35	1	D	
17	30	0		
18	30	0		
19	30	0		
20	30	1	D	
21	25	0		
22	25	1	D	
23	20	0		
24	20	0		
25	20	0		
26	20	0		
27	20	1	D	
28	15	0		
29	15	0		
30	15	1	D	
31	10	0		
32	10	0		
33	10	0		
34	10	0		
35	10	0		
36	10	0	U	1
37	12.5	0		
38	12.5	0		
39	12.5	0		
40	12.5	0		
41	12.5	0		
42	12.5	0	U	
43	18.75	0		
44	18.75	1	D	2
45	15.62	0		
46	15.62	0		
47	15.62	0		
48	15.62	0		
49	15.62	0		
50	15.62	0	U	3

TEST 6

Fuze: M567, *Lot 53, W/O Pull Wire

*Improved Delay Holder and Spacer

Projectile: 81mm, M374

Date: 1 November 1975

Orientation: Horizaontal Selector Cup Up

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	100	0		
2	100	0		
3	100	0		
4	100	1	D	
5	90	0		
6	90	0		
7	90	0		
8	90	0		
9	90	0		
10	90	0		
11	90	0		
11	95	0		
12	95	0		
13	95	0		
14	95	0		
15	95	0		
16	95	0		
17	97.5	0		
18	97.5	0		
19	97.5	0		
20	97.5	0		
21	97.5	0		
22	97.5	0		
23	98.75	0		
24	98.75	0		
25	98.75	0		
26	98.75	0		
27	98.75	0		
28	98.75	0		
29	99.37	0		
30	99.37	0		
31	99.37	0		
32	99.37	0		
33	99.37	0		
34	99.37	0		
35	100	0		
36	100	0		
37	100	0		
38	100	0		
39	100	0		
40	100	0		
41	100	0		
42	100	0		
43	100	0		
44	100	0		
45	100	0		
46	100	0		
47	100	0		
48	100	0		

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
49	100	1		
50	100	0		

TEST 7

Fuze: M524, W/Pull Wire

Projectile: 81mm, M374

Date: 21 October 1975

Orientation: 10^{o} Horizontal, Base Down, Trigger Down

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	40	0		
2	30	0		
3	30	0		
4	30	0		
5	30	0		
6	30	0		
7	30	0		
8	30	0		
9	30	0		
10	30	0		
11	30	0		
12	30	0		
13	30	0		
14	30	0		
15	30	0		
16	30	0		
17	30	0		
18	30	0		
19	30	0		
20	30	0		
21	30	0		
22	30	0		
23	30	0		
24	30	0		
25	30	0		
26	30	0		
27	30	0		
28	30	0		
29	30	0		
30	30	0		
31	30	0		
32	30	0		
33	30	0		
34	30	0		
35	30	0		
36	30	0		
37	30	0		
38	30	0		
39	30	0		

Trail	Stress X (I)	Response Y (1)	Response Type	Change Number
40	30	0		
41	30	0		
42	30	0		
43	30	0		
44	30	0		
45	30	0		
46	30	0		
47	30	0		
48	30	0		
49	30	0		
50	30	0		

TEST 8

Fuze: M525, W/Pull Wire

Projectile: 60mm, XM720

Date: 21 October 1975

Orientation: Base Down

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	40	0		
2	60	0		
3	80	0		
4	100	0		
5	100	0		
6	100	0		
7	100	0		
8	100	0		
9	100	0		
10	100	0		
11	100	0		
12	100	0		
13	100	0		
14	100	0		
15	100	0		
16	100	0		
17	100	0		
18	100	0		
19	100	0		
20	100	0		
21	100	0		
22	100	0		
23	100	0		
24	100	0		
25	100	0		
26	100	0		
27	100	0		
28	100	0		
29	100	0		
30	100	0		
31	100	0		
32	100	0		

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
33	100	0		
34	100	0		
35	100	0		
36	100	0		
37	100	0		
38	100	0		
39	100	0		
40	100	0		
41	100	0		
42	100	0		
43	100	0		
44	100	0		
45	100	0		
46	100	0		
47	100	0		
48	100	0		
49	100	0		
50	100	0		

TEST 9

Fuze: M567, *Lot 53, W/O Pull Wire
*Improved Delay Holder and Spacer

Projectile: 81mm, M374

Date: 1 November 1975

Orientation: Base Down

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	100	0		
2	100	0		
3	100	0		
4	100	0		
5	100	0		
6	100	0		
7	100	0		
8	100	0		
9	100	0		
10	100	0		
11	100	0		
12	100	0		
13	100	0		
14	100	0		
15	100	0		
16	100	0		
17	100	0		
18	100	0		
19	100	0		
20	100	0		
21	100	0		
22	100	0		
23	100	0		
24	100	0		
25	100	0		

Trail	Stess X (I)	Response Y (I)	Response Type	Change Number
26	100	0		
27	100	0		
28	100	0		
29	100	0		
30	100	0		
31	100	0		
32	100	0		
33	100	0		
34	100	0		
35	100	0		
36	100	0		
37	100	0		
38	100	0		
39	100	0		
40	100	0		
41	100	0		
42	100	0		
43	100	0		
44	100	0		
45	100	0		
46	100	0		
47	100	0		
48	100	0		
49	100	0		
50	100	0		

TEST 10

Fuze: M567, W/Long Pull Wire

Projectile: 81 mm, M374

Date: 22 October 1975

Orientation: Base Down

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	100	0		
2	100	0		
3	100	0		
4	100	0		
5	100	0		
6	100	0		
7	100	0		
8	100	0		
9	100	0		
10	100	0		
11	100	0		
12	100	0		
13	100	0		
14	100	0		
15	100	0		
16	100	0		
17	100	0		

Trail	Stress X (1)	Response Y (1)	Response Type	Change Number
18	100	0		
19	100	0		
20	100	0		
21	100	0		
22	100	0		
23	100	0		
24	100	0		
25	100	0		
26	100	0		
27	100	0		
28	100	0		
29	100	[illegible]		
30	100	0		
31	100	0		
32	100	0		
33	100	0		
34	100	0		
35	100	0		
36	100	0		
37	100	0		
38	100	0		
39	100	0		
40	100	0		
41	100	0		
42	100	0		
43	100	0		
44	100	0		
45	100	0		
46	100	0		
47	100	0		
48	100	0		
49	100	0		
50	100	0		

TEST 11

Fuze: M567, W/O Pull Wire

Projectile: 81mm, M374

Date: 10 October 1975

Orientation: Base Down

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	5	0		
2	5	0		
3	5	0		
4	5	0		
5	5	0		
6	5	0	U	
7	10	0		
8	10	0		
9	10	0		

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
10	10	0		
11	10	0		
12	10	0	U	
13	12.5	0		
14	12.5	0		
15	12.5	0		
16	18.75	0		
17	18.75	0		
18	60.00			
19	60.00	0		
20	80.00	0		
21	100.00	0		
22	100.00	0		
23	100.00	0		
24	100.00	0		
25	100.00			
26	100.00	0		
27	100.00	0		
28	100.00	0		
29	100.00	0		
30	100.00	0		
31	100.00	0		
32	100.00	0		
33	100.00	0		
34	100.00	0		
35	100.00	0		
36	100.00	0		
37	100.00	0		
38	100.00	0		
39	100.00	0		
40	100.00	0		
41	100.00	0		
42	100.00	0		
43	100.00	0		
44	100.00	0		
45	100.00	0		
46	100.00	0		
47	100.00	0		
48	100.00	0		
49	100.00	0		
50	100.00	0		

TEST 12

Fuze: M567, *Lot 53, W/Long Pull Wire
*Improved Delay Holder and Spacer

Projectile: 81mm, M374

Date: 1 November 1975

Orientation: Base Down

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	100	0		
2	100	0		
3	100	0		
4	100	0		
5	100	0		
6	100	0		
7	100	0		
8	100	0		
9	100	0		
10	100	0		
11	100	0		
12	100	0		
13	100	0		
14	100	0		
15	100	0		
16	100	0		
17	100	0		
18	100	0		
19	100	0		
20	100	0		
21	100	0		
22	100	0		
23	100	0		
24	100	0		
25	100	0		
26	100	0		
27	100	0		
28	100	0		
29	100	0		
30	100	0		
31	100	0		
32	100	0		
33	100	0		
34	100	0		
35	100	0		
36	100	0		
37	100	0		
38	100	0		
39	100	0		
40	100	0		
41	100	0		
42	100	0		
43	100	0		
44	100	0		
45	100	0		
46	100	0		
47	100	0		
48	100	0		
49	100	0		
50	100	1		

TEST 13

Fuze: M567, *Lot 53, W/Long Pull Wire
*Improved delay holder and spacer

Projectile: 81mm, M374

Date: 1 November 1975

Orientation: Base Down

Trail	Stress X (I)	Response Y (I)	Response Type	Change Number
1	100	0		
2	100	0		
3	100	0		
4	100	0		
5	100	0		
6	100	0		
7	100	0		
8	100	0		
9	100	0		
10	100	0		
11	100	0		
12	100	0		
13	100	0		
14	100	0		
15	100	0		
16	100	0		
17	100	0		
18	100	0		
19	100	0		
20	100	0		
21	100	0		
22	100	0		
23	100	0		
24	100	0		
25	100	0		
26	100	0		
27	100	0		
28	100	0		
29	100	0		
30	100	0		
31	100	0		
32	100	0		
33	100	0		
34	100	0		
35	100	0		
36	100	0		
37	100	0		
38	100	0		
39	100	0		
40	100	0		
41	100	0		
42	100	0		
43	100	0		
44	100	0		
45	100	0		
46	100	0		
47	100	0		
48	100	0		
49	100	0		
50	100	0		

PACKAGED DROP DATA

PACKAGED DROP TEST (Various Drop Heights) Date of Test: 4 Nov 75 R. Stone

XM935 Fuze, lot BWV-2-2 Long pullwire. Fuzes assembled to XM720 cartridges, Standard Packing. All drops were made with the selector caps oriented upward. Each drop involved sixteen (16) fuzes. No fuze was tested more than once.

RESULTS:

I. First 40 foot drop -

None of the fuzes indicated signs of slider movement.

II. Second 40 foot drop -

Six fuzes exhibited slight slider movement after the pullwire was withdrawn. In no case was any portion of the detonator visible.

III. First 80 foot drop -

Five fuzes exhibited slight slider movement after the pullwire was withdrawn. In no case was any portion of the detonator visible.

IV. Second 80 foot drop. -

One fuze: Same comments as above.

V. 100 foot drop -

a. Seven fuzes: Same comments as above.

b. One fuze: Slight slider movement before pullwire was withdrawn. Additional slider movement after pullwire was withdrawn. Approximately 3/32 inch of detonator visible through booster lead hole.

FORTY FOOT PACKAGED DROP TEST Date of Test: 8 November 75 R. Stone

M567 Fuze - Lot BWV -2-2 (Long pullwire) 11 boxes dropped, 3 rounds per box, total 33 fuzes tested. All fuzes oriented with selector caps up for packaged 40 foot drop. In 20 of the fuzes, the slider had moved slightly. In no case was any portion of the detonator visible.

II. Second Drop - Thirty Foot - No Pullwire:

5 Fuzes Tested -

RESULTS: Slight Slider movement. No portion of Detonator visible. All 5 Fuzes.

III Third Drop - Forty Foot - With Pullwire:

20 Fuzes Tested

RESULTS: 18 Fuzes: Same as Para. II above.

2 Fuzes: No evidence of slider movement observed.

REPETITIVE BARE DROP DATA

BARE FIVE FOOT, TEN FOOT DROP TESTS (Multiple Drop) Date of Test: 6 Nov 75

GROUP III XM935 Fuzes - New Delay Holders, New Spacer Plates, New Firing Pins.

All drops horizontal; selector caps oriented upward.

I. Five foot multiple drop test -

Five fuzes, each dropped five times, five feet.

RESULTS: All five fuzes exhibited some slider movement. In no case was any portion of the detonator visible through the booster lead hole.

II. Ten foot multiple drop test -

RESULTS:

One Fuze: Pullwire came out 1/4 inch after second drop. Could not be reseated. This fuze withdrawn from further testing.

Four Fuzes: All exhibited some slider movement. In no case was any portion of the detonator visible through the booster lead hole.

BARE TWENTY FOOT, THIRTY FOOT, FORTY FOOT DROP TEST Date of Test: 7 Nov 75

GROUP I - XM935 Fuzes - New Delay Holder (Ribbed), New Spacer, Firing Pin Ground Off.

Fuzes assembled to 81MM Cartridge. All drops horizontal, selector cap up.

I. First Drop - Twenty Foot - No Pullwire:

5 Fuzes tested -

RESULTS: 4 Fuzes - Slight Slider movement. No portion of detonator visible.

1 Fuze - Detonator Crimp just visible.

FIVE FOOT BARE DROP TEST (Multiple Drop) Date of Test: 11 Nov 75 R. Stone

XM935 Fuze - Group I - New Delay Element Holder, Long Pullwire,

Firing pin point ground off.

Horizontal Drop - Selector Cap up.

Ten fuzes dropped 5' five times, horizontal, selector cap up. Pullwire not withdrawn until after the fifth drop.

RESULTS: 10/10 OK

Slight slider movement in all 10 samples. No portion of detonator visible in all 10 samples.

FIVE FOOT BARE DROP TEST Date of Test: 17, 18 November 1975 R. Stone

Fuze, XM935 - Lot BWV 2-2 (Long pullwire) 10 fuzes assembled to XM720 Cartridge (60MM) 10 Fuzes assembled to M374 Cartridge (81MM)

Each round dropped in each of the 5 basic orientations one time only. Except for the nose down and the base down drops, in all other drops, the selector cap fared upward. The pullwire was removed only after the last drop. The order in which the rounds were dropped was:

1. Side down.
2. Base Down
3. Nose down
4. Base 45° Down
5. Nose 45° Down

RESULTS: In all samples, slight slider movement was detected. In no case was any portion of the detonator visible.

FIVE FOOT BARE DROP TEST   Date of Test: 8 November 75 R. Stone

XM935 Fuze - Lot BWV 2-2 (Long Pullwire)

Horizontal Drop - Selector Cap oriented up.

PART I - 10 Fuzes - Examination after removal of the pullwire after one drop.

RESULTS: 10/10 OK

a. Slight slider movement in all 10 samples.

b. No portion of detonator visible in all 10 samples.

PART II - 10 Fuzes - Examination after removal of pullwire after two drops.

RESULTS: 4/10 OK

a. Slight slider movement, no portion of the detonator visible in 4 samples.

b. 5 Fuzes armed. Detonator fully in line with booster lead hole.

c. 1 fuze: Half of detonator visible through booster lead hole.

PART III - 10 Fuzes - Examination after removal of pullwire after three drops.

RESULTS: 3/10 OK

a. 3 Fuzes had bent pullwire, could not be reseated, not armed.

b. 1 Fuze removed from test after second drop. Pullwire partially out. Could not be reseated. Not armed.

c. 4 Fuzes: Slider moved to detonator - in line position after pullwire was withdrawn.

d. 2 Fuzes: Half of detonator visible through booster lead hole.

PART IV - 5 Fuzes - Examination after removal of pullwire after five drops.

RESULTS: 0/5 OK

a. 1 fuze removed from the test after second drop. Pullwire partially out. Could not be reseated; not armed.

b. 4 Fuzes: Slider moved to detonator - In-line position; two armed with pullwire in place, two armed as pullwire was withdrawn.

#002

ENGINEER: M. Della Terza

LAB: AD&ED, FEB, Mortar Section

REVIEWED BY: ________________

DATE: 25 November 75

ITEM: Fuze, PD, M567/M935

TEST OBJECTIVE:

1. Test newly designed firing pin's capability to prevent slider assembly from moving into the fully armed position after a five foot bare fuze drop.

CONCLUSIONS & RECOMMENDATIONS:

1. Firing Pin Mod-One, drawing XM720-002, Rev D will not independently withstand three successive five-foot drops when the M567 Fuze is oriented in the severest drop position; i.e., selector cap up.

2. Redesign the firing pin so that the .083 in. dia. shank will fail to a safe condition and not to a potentially catostrophic condition.

BACKGROUND:

This testing is part of the M567/M935 malfunction program.

DISCRIPTION OF MATERIAL:

1. Fuze Front Body Assemblies - BWV-07-75-2-2.
2. Firing Pin replaced with Firing Pin, Mod 1, dwg. XM720-002 Rev D, 11-07-75.
3. No Firing Pin Spring.
4. Pull Wire Assembly removed for test.
5. Inert loaded 81mm shells with empty M567 Rear Bodies.
6. M53 Delay Element also ~~detentions~~ detents slider.
7. LEAD ASSEMBLY REMOVED.

DATA:

FIVE FOOT DROP - M567 FUZE ON 81MM SHELLS
(Selector Cap Oriented in the Up Position)

FUZE NO.	DROP # 1	2	3
1	PSM*	UNCHANGED	FULLY ARMED
2	PSM	UNCHANGED	FULLY ARMED
3	OK	PSM	UNCHANGED
4	OK	PSM	UNCHANGED
5	PSM (more than other)	S.Q. Det Edge Visible	FULLY ARMED

*PARTIAL SLIDER MOVEMENT

FIVE FOOT DROP - M567 FUZE ON 81MM SHELLS

(Continued)

FUZE NO.	1	2	3
6	PSM	UNCHANGED	S.Q. DET EDGE VISIBLE
7	PSM	UNCHANGED	UNCHANGED
8	PSM	UNCHANGED	1/2 S.Q. DET VISIBLE
9	PSM	UNCHANGED	UNCHANGED
10	PSM	UNCHANGED	UNCHANGED
11	OK	PSM	UNCHANGED
12	PSM	UNCHANGED	UNCHANGED
13	PSM	UNCHANGED	UNCHANGED
14	PSM	UNCHANGED	UNCHANGED
15	PSM	UNCHANGED	FULLY ARMED

DISCUSSION OF RESULTS:

Examination of all fifteen (15) firing pins after the third and final drop showed that only five pins, though severly bent below the .035 inch radius, were capable of preventing the slider from moving into the fully armed position. The remaining ten firing pins were sheared just below where the .035 inch radius blends into the .083 inch dia. shank. Remaining on the firing pin was approximately a .040 inch projection which might be capable of piercing a detonator closing disc on setback causing an in-bore function. It would be desirable to have the firing pin shank fail to a safe condition, even if this task requires reducing the firing pins slider detenting strength, to eliminate any possible catostrophic failure. By reducing the .035 inch radius to a sharp corner or by undercutting in the area one could obtain a clean shear in an area that would be sufficiently distant from either detonator to prevent detonator penetration by the firing pins downward travel during setback.

TEST PROCEDURE:

Each round was oriented with the selector cap up then dropped horizontally five feet unto the steel plate at the bldg. 3109 drop tower base. Each front body assembly was removed after each drop and examined visually through the lead hole for slider movement. After the test, all firing pins were removed for visual inspection.

SUMMARY OF RESULTS:

SUCCESSIVE FIVE-FOOT DROP TESTS - M567 FUZE (15 TOTAL)

DROP #	REMARKS
1.	12/15 exhibited partial slider movement (psm)
2.	All had p.s.m. with edge of S.Q. det visible for one test sample.
3*	4 - fully armed 1 - edge of S.Q. det. visible 1 - 1/2 of S.Q. det visible

*Of the remaining fuzes that exhibited only partial slider movement, four had the firing pins sheared at the .030 in. radius.

ENGINEER: M. Della Terza LAB: AD&ED, FEB, Mortar Sec.

REVIEWED BY: ______________ DATE: 25 November 1975

ITEM: FUZE, PD, M567/M935 TEST NO.: 001

TEST OBJECTIVE:

Test capability of Firing Pin dwg. XM720-027 to prevent the Slider Assembly from moving into the fully armed position after repetitive five-foot drops.

CONCLUSIONS:

1) Firing Pin dwg. XM720-027 will prevent the Slider Assembly from moving into the fully armed position after ten repetitive five-foot bare drops.

2) No appreciable bending of the firing pin shank occurs for additional drops after the first five drops.

DESCRIPTION OF MATERIAL:

1) Fuze Front Body Assemblies - BWV-07-75-2-2.

2) Firing Pin dwg. XM720-027 with Firing Pin Spring.

3) Pull Wire Assembly removed for test.

4) Inert loaded 81MM Cartridges with empty M567 Rear Bodies.

5) M53 Delay Element detents Slider Assembly.

6) Lead Assembly removed.

DATA:

M567 REPETITIVE FIVE-FOOT DROP TEST
(SELECTOR CAP ORIENTED IN THE UP POSITION)

FUZE NO.	DROP NO.									
	1	2	3	4	5	6	7	8	9	10
1	*PSM	UN-CHANGED	SEE SQ EDGE	UNCH	UNCH	UNCH	UNCH	UNCH	UNCH	UNCH
2	PSM	UNCH	SEE SQ EDGE	UNCH	UNCH	UNCH	UNCH	UNCH	UNCH	UNCH

M567 REPETITIVE FIVE-FOOT DROP TEST
(SELECTOR CAP ORIENTED IN THE UP POSITION)

(Continued)

FUZE NO.	DROP NO.									
	1	2	3	4	5	6	7	8	9	10
3	PSM	UNCH	UNCH	UNCH	SEE SQ EDGE	UNCH	UNCH	UNCH	UNCH	UNCH
4	PSM	UNCH	UNCH	SEE SQ EDGE	UNCH	UNCH	UNCH	UNCH	UNCH	UNCH
5	PSM	UNCH	UNCH	SEE SQ EDGE	UNCH	UNCH	UNCH	UNCH	UNCH	UNCH
6	PSM	UNCH	UNCH	UNCH	SEE SQ EDGE					
7	PSM	UNCH	UNCH	SEE SQ EDGE	UNCH					
8	PSM	UNCH	UNCH	UNCH	SEE SQ EDGE					
9	PSM	UNCH	UNCH	UNCH	SEE SQ EDGE					
10	PSM	UNCH	UNCH	UNCH	UNCH					

* PARTIAL SLIDER MOVEMENT

DISCUSSION OF RESULTS:

After examining and comparing the firing pins that were subjected to five repetitive five-foot drops and those subjected to ten repetitive five-foot drops, it was noticed that no appreciable firing pin bending of the .083 in. steel shank occurs after the initial five drops. The .083 in. firing pin shank which is manufactured from 303 stainless steel absorbs the energy of the five-foot drops by bending until it reaches a position where it is wedged between the slider and the inner halves. At this point, the shank cannot bend any further and is of sufficient material strength to resist failure by shearing as the 7075-T6 aluminum shanks did.

At the conclusion of all testing it was observed that slider shanks were broken off of units # 1, 2, 3, 4, 5, 6 and 8. Units # 1 thru 5 were subjected to ten repetitive drops.

TEST PROCEDURE:

Each round was oriented with the selector cap in the up position then dropped five feet horizontally into the steel plate at the base of the drop tower near Bldg. 3145. Each front body assembly was removed after individual drops to be examined visually through the lead hole for slider movement. After the test, all firing pins and slider assemblies were removed for visual inspection.

SUMMARY:

DATA SUMMARY - TEST # 001 REPETITIVE FIVE-FOOT DROP TEST M567 (10 TOTAL)

AFTER DROP #	SUMMARY
1	ALL EXHIBITED PARTIAL SLIDER MOVEMENT
3	2/10, S.Q. EDGE VISIBLE (NOT ARMED)
4	5/10, S.Q. EDGE VISIBLE (NOT ARMED)
5	9/10, S.Q. EDGE VISIBLE (NOT ARMED)
6	5/5, S.Q. EDGE VISIBLE (NOT ARMED)
10	CONCLUSION OF TEST, 5/5 S.Q. EDGE VISIBLE (NOT ARMED)

ENGINEER: M. Della Terza   LAB: AD&ED, FEB, Mortar Sec.

REVIEWED BY: ____________   DATE: 2 December 1975

ITEM: Fuze, PD, M567/M935   TEST NO.: 003

TEST OBJECTIVE:

Test the ability of the two-piece firing pin dwg.9299424 to be an independent safety for the forty foot drop test.

CONCLUSIONS AND RECOMMENDATIONS:

1. Firing Pin Dwg. 9299424 will, independently, prevent the M567 Slider Assembly from arming for the forty foot drop test.

2. A high percentage of the slider shanks break when the M567 Fuze is subjected to the forty foot drop test.

3. Recommend a push test on a loaded slider assembly in the M567 Fuze with only the firing pin serving as a detent, thereby determining the mode of failure and the force to obtain this failure.

BACKGROUND:

This testing is part of the M567/M935 Malfunction program.

DESCRIPTION OF MATERIAL:

1) Front Body Assemblies BWV 07-75-2-2 without lead assemblies and pullwire assemblies and with subverted M53 Delay Elements.

2) Inert filled 81mm shells with empty M567 rear bodies attached.

3) Firing pins dwg. 9299424.

DATA:

FORTY FOOT DROP TEST OF PIN, FIRING, DWG. 9299424 FOR FUZE, PD, M567/M935 (10 DROPS TOTAL - Selector Cap Up)

FUZE NO.	REMARKS
1	Unarmed, Partial Slider Movement (PSM)
2	Unarmed, PSM
3	Unarmed, PSM, Slider Shank Broken (SSB)
4	Unarmed, PSM
5	Unarmed, PSM
1A	Unarmed, PSM

FUZE NO.	REMARKS
2A	Unarmed, PSM, SSB, Firing Pin Head broken
3A	Unarmed, PSM
4A	Unarmed, PSM, SSB
5A -	Unarmed, PSM, SSB

DISCUSSION OF RESULTS:

For severe firing pin tip bending, slider arming is prevented because the firing pin shank is wedged between the inner halves and the slider. Although the slider is firmly locked in this position, the following possibilities for slider arming or detonator functioning exist:

1) Further slider deformation can occur allowing the S.Q. detonator to move under the bent firing pin shank.

2) Severe S.Q. detonator deformation can occur causing an explosion in a position which would probably initiate the lead assembly.

3) Inner half deformation can occur in the portion of the inner halves that the firing pin is wedged against causing the slider assembly to pass underneath the bent firing pin.

The above possibilities should be fully investigated to discover at what force level they will occur and if these forces can ever be experienced in either the M567 or M935. One might find that any S.Q. detonator deformation would cause non-propagation. Further, one might discover that the severely bent firing pin may not be capable of functioning the S.Q. detonator. Therefore, failure to a safe condition (a dud in this instance) could be obtained.

Finally, it was observed for several drops that the pair of rounds didn't horizontally imapct the steel plate, but rather impacted at approximately a 20° angle.

TEST PROCEDURE:

The test M567 Fuze were threaded into inert filled 81mm shells, strapped in pairs with the selector cap oriented up, and dropped forty feet onto a steel plate. The rounds were dropped in pairs, nose to tail, to provide flight stability during the drop.

SUMMARY:

FORTY FOOT DROP TEST OF PIN, FIRING DWG. 9299424 FOR FUZE, PD, M567/M935 (10 Drop total)

1. 10/10 were unarmed, but exhibited partial slider movement.
2. 4/10 had broken slider shanks.
3. 1/10 had a broken firing pin head.

APPENDIX D

SEQUENTIAL ROUGH HANDLING

SUMMARY OF SEQUENTIAL ROUGH HANDLING TEST

ROUGH HANDLING TESTS (MTP-4-2-602)

OBJECTIVE

The objective of this test procedure is to provide guidance for evaluating the capability of military items to withstand the possible shocks and vibrations that could be encountered as a consequence of transport or employment on the battlefield.

BACKGROUND

One of the operational environments to be considered during engineering testing is that of rough handling. Rough handling is a generic term used to describe the many bumps, drops, and severe vibrations that Army materiel is liable to encounter, particularly as related to handling on the battlefield where materiel may be dropped from the back of a truck, thrown loose on the back of a truck, dropped by air, etc.

The tests to simulate rough handling were devised after observations of materiel handling by troops, and by measurements of shock and vibration environments of vehicles. Many of these tests are part of the safety evaluation and therefore, a prerequisite to a safety release.

In general, commodities suitable for round handling tests are those that could be carried as cargo in trucks, or on the person of soldiers, and would include items such as munition (MTP 4-2-504), rifles (MTP 3-2-059), rockets (MTP 4-2-015), radios and mortars (MTP 3-2-050).

LIMITATIONS

Transportation-vibration tests simulating transport of packaged items by rail, air, ship, trailer, and truck, including packaged, tied-down transportation on the battlefield, are not considered to be in the "rough handling" category; such tests are covered in MTP 4-2-804.

FIVE FOOT DROP TEST

OBJECTIVE

The five foot drop test is a test to simulate the accidental dropping of unpackaged munitions that might occur during truckage, and the accidental dropping of a bare round by a gun crew preparing to load a weapon. Munitions dropped in this manner are usually expacted to be able to perform satisfactorily.

The five foot drop test is also used for testing fuzes as described in MIL-STD-331. When the fuze is not visibly damaged, it is expected to function properly when fired from a projectile. When visibly damaged, it is expected only to be safe to dispose of.

This test is also used for certain hand-carried equipment

TEST EQUIPMENT

Facilities suitable for the five foot drop test are described in MTP 4-2-601 and MIL-STD-331. Munitions are dropped by a quick-release hook suspended from a tower onto a high-hardness steel plate appropriately supported.

PROCEDURE

Fuzes

When possible, live fuzes containing all explosive elements are subjected to the five foot drop test assembled to an inert warhead, the heaviest one for which the fuze is made. Twelve fuzes are dropped, two each under the same conditions prescribed for projectiles. (Fig D-1) Following each drop, the fuze is examined and any damage or indication of functioning is recorded. When the fuze does not appear to have suffered any obvious ill effects, it is

given a standard fuze performance test. (It is assumed that a soldier seeing no damage would assume that the fuze is all right). Damaged fuzes would not be tested further. Any indication that the fuze had functioned so that the primer had been set off is considered to be unacceptable from the safety viewpoint. It is not unusual for the drops that are nose down and 45° to nose to result in damaged fuzes, and for the fuzes dropped in the other orientations to remain undamaged.

The five foot drop test of fuzes is covered in MIL-STD-331.

In some instances, the five foot drop test of fuzes is part of a sequence as described in Figure D-1. Usually the test prescribed above is conducted at both -50°F and +145°F.

SEVEN-FOOT DROP TEST

OBJECTIVE

The seven foot drop test is designed to simulate the condition of a hovering helicopter dropping munitions or equipment from a sling, or dropping during the hasty unloading of munitions stacked on a truck. The munitions are assumed to be in their shipping crates or packages and, after the drop, should be able to perform as well as undropped ammunition.

TEST EQUIPMENT

Facilities suitable for the seven foot drop test are the same as those used in the five foot, ten foot, and forty foot drop tests which are described in MTP 4-2-601. Munitions are dropped by a quick-release hook from a tower onto a high-hardness steel plate appropriately supported.

PROCEDURE

All items dropped are contained in their shipping package. The number of packages dropped and the sequence of dropping is dependent upon the type of packaging and the number of test items in a package. Usually the seven foot drop test is made the first step of a sequential rough handling test series. Sample size and sequences are contained in Figure D-1. Some packages are dropped once in one of six orientations; i.e., flat, side, base down,

nose down, 45° to nose, and 45° to base. Other packages are dropped six times in all of the six orientations. After each drop visible damage is recorded. Following all drops certain packages are selected for opening and the contents inspected. The exposed test items are then subjected to standard performance tests. In the case of cartridges, for example, test measurements would include muzzle velocity, chamber pressure, accuracy, and dispersion. The drops should not affect the performance.

Tests are ordinarily conducted at -50°F and +145°F. Sufficient conditioning time should be used to assure complete temperature stabilization. Tests must be conducted as rapidly as possible to avoid temperature recovery. Packages that are dropped six times may have to be placed in the climatic chamber for reconditioning after the third drop.

Packaged items other than munitions may be subjected to the seven foot drop test. Packaged weapons of the type that are hand carried would fall within this category.

LOOSE CARGO TEST

OBJECTIVE

The "loose cargo test" is conducted to determine the effects of rough handling on unpackaged items issued to the soldier. This test simulates the particular rough handling that occurs when, for personal comfort, a soldier divests himself of gear by depositing it on a truck floor where it rides as loose cargo. Many of the items issued to the individual soldier are explosive loaded, and these, of course, are no longer protected by their shipping containers after issuance to troops. Thus, hand grenades, clips of ammunition, foxhole digging aids, small arms, and like items may sometimes be carried as loose cargo on vehicles. Feedback information on field experience under this environment has demonstrated the desirability of this subtest for such items.

TEST EQUIPMENT

Package test. The package test illustrated is equipped with a steel deck 6 feet wide and 8 feet long and has a load capacity of 3000 pounds. It is driven by a variable speed motor through a link belt to two cams in phase that impart a 1-inch circular double amplitude. A maximum output of 1.5 g is attainable with this tester at approximately 5.5 Hertz.

PROCEDURE

a. After careful inspection place the test items upon the table of the package tester, which must be provided with sideboards to contain the test items during operation. The test items are not tied down in any manner.

b. Operate the test for 30 minutes at a frequency of 5.0 Hertz at 1.3 g.

NOTE: 1. The severity of the test environment is based in part upon an informal agreement between Materiel Test Directorate, Aberdeen Proving Ground, and the U.S. Army Combat Developments Command Ordnance Agency, that transport over a Belgian block course constitutes an adequate exposure of loosely stowed items. A 150-mile simulation for artillery ammunition has been accepted in international agreement.

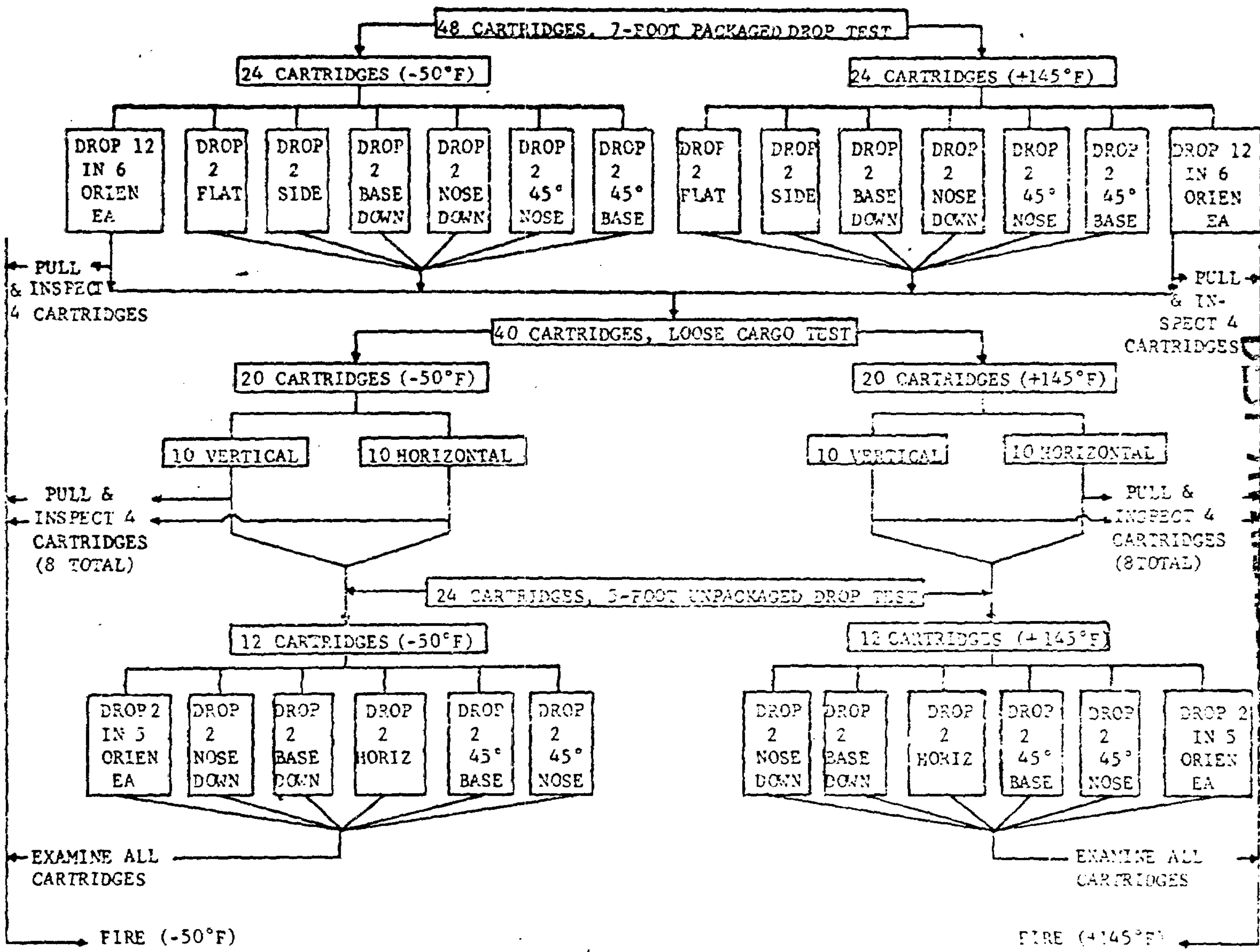
2. Report DPS-1937, dtd March 1966, Special Study of Test Procedure for Laboratory Simulation of Rough Handling by Tolen, J. A. and Lefevre, G.F., Aberdeen Proving Ground; establishes equivalent damage on a package tester. From study data it has been determined that operation for 30 minutes at a frequency of 5.0 Hertz at 1.3 g in the vertical mode is equivalent to 150 miles of loose cargo transport over Belgian block.

c. After the test cycle, remove the test items and:

1) Visually inspect for damage. Other inspections such as x-ray and magnetic particle may be performed as dictated by engineering judgment.

2) Conduct functioning tests to assess any effect of the rough handling environment on the performance of the item. These functioning tests generally are concerned with both safety and operability of the item and should be conducted in accordance with the MTP appropriate to the class of item under test.

FIGURE D-1



Sequential Rough Handling Test for Artillery, Mortar, and Recoilless Rifle Ammunition: One or Two Items per Package - Complete Rounds.

SUMMARY OF SEQUENTIAL ROUGH HANDLING TEST RESULTS

TESTS TO REQUIREMENTS

SEQUENTIAL ROUGH HANDLING

MORTAR ROUND						81MM	60MM	60MM
FIRING PIN	ORIGINAL	X	-	X	-	X	X	X
DELAY HOLDER	ORIGINAL	-	X	X	-	X	X	X
	RIBBED	-	-	-	X	-	-	-
PULL WIRE	SHORT	-	-	X	-	-	-	-
	LONG	-	-	-	-	X	X	X
		5/48	3/48	5/48	0/48	0/192	0/160	0/160

21 NOV 75

FUZE FUNCTIONING IN SRH TESTS

Fuze	SRH	REF	No. Tested	No. Not Fired	Functioning Rates* PD	PD LC	PD LC BD	Avg.
M567	48	APG MT-4632 Apr 75	192	3**	1.00 (0/23)	0.968 (2/63)	0.874 (13/103)	0.921 (15/189)
XM935	48	APG MT-4536 Oct 74	48	0	0.889 (2/18)	1.00 (0/6)	1.00 (0/24)	0.958 (2/48)
XM935	160	LWCMS DT II	160	10***	1.00 (0/33)	0.954 (1/22)	0.768 (22/95)	0.847 (23/150)

* Functioning Rates are presented as the numbers of fuzes reported to function at impact as a fraction of the numbers tested. The fractions in parentheses indicate the number of duds recorded over the number tested. PD package drop, LC - loose cargo, BD - bare drop. Avg - average.

** Could not be uploaded for firing.

*** One premature, nine not fired.

SEQUENTIAL ROUGH HANDLING TEST

DATE: 21 - 15 Nov. 1975

R. Stone

Fuze: M525

Lot: PA-1-3

Qty: 7747

Summary of Results

No. Tested: 160

No. Without Visible Damage, No Safety Features Defected: 92

No. Damaged (Probable Dud): 64

No. Fuzes Armed: None

No. Head Assemblies Armed: 4

Quantity Tested: 80 Hot (+145^{0}F)

80 Cold (-50^{0}F)

Test Method:

1. a) Fuzes assembled to inert XM720 Cartridges

   b) Cartridges packed in fiberboard containers

   c) 8 fiberboard containers per metal can.

   d) 2 metal cans per wireboard wood box

   e) Total: 10 boxes, 5 conditioned at each temperature

2. Drop all boxes in 6 orientations, 7 feet.

3. a) Pull 2 boxes (1 hot, 1 cold), Inspect as follows:

   b) Check for safety pin retention

   c) Check for pull wire, safety wire retention

   d) Check for other damage

   e) Withdraw pull wire from head assembly

   f) Remove head assembly from body assembly

   g) Note whether head assembly has armed

4. Results: None of the fuzes were damaged. None of the safety features were damaged or defected.

5. Subject remaining 8 boxes (4 hot, 4 cold) to loose cargo test; 2 boxes, each temperature vertical, 2 boxes, each temperature horizontal

6. Inspect 14 rounds from each temperature phase, total 28 rounds. 7 rounds, each temperature from vertical test. 7 rounds each temperature from horizontal test. Inspect per Para. 3b thru 3g, above.

7. Results: Same as Para. 4 above.

8. Inspect remaining rounds per Para. 3b thru 3d above.

9. Results: No visible damage observed. No pull wires or safety wires were displaced.

10. Five foot unpackaged drop test of remaining 100 rounds (50 Hot, 50 Cold)

11. Inspect per Para. 3b thru 3 g above.

12. Results:

Hot: 19 OK (Same as Para. 4 above)
29 Damaged Head Assemblies (Probable Dud)
2 Armed Head Assemblies (With Pull Wire in Place; 1 started to run down where pull wire was withdrawn, did not complete arming cycle).

No. Safety Pins Ejected

Cold: 13 OK (Same as Para. 4 above)
35 Damaged Head Assemblies (Probable Dud)
2 Armed Head Assemblies (Both with pull wire in place)
No Saqety pins ejected

13. Additional data pertaining to armed head assemblies:

Fuze. No.	Temp.	Loose Cargo Test Orientation	1st 5' Drop Orientation	2nd 5' Drop Orientation
77	+145^{o}F	Horizontal	Side Down	Side Down
78A	+145^{o}F	Vertical	Side Down	Base Dwon 45^o
89	-50^{o}F	Horizontal	Nose Down 45^o	Side Down
91	-50^{o}F	Vertical	Side Down	Base Down 45^o

14. Additional Data pertaining to fuzes:

Lot: PA-1-3

Handling Lot: BWC=11=1

Lot Qty: 7746

SEQUENTIAL ROUGH HANDLING TEST

Packaged Drop Test (Various Drop Heights)
M567 Fuze, Group III - New Delay Holder (Ribbed)
New Firing Pins
New Spacer Plates

Selector caps oriented upward in all drops. Fuzes assembled to M374 Ctgs,. Standard Packing for 81MM Rounds. Each drop involved 3 fuzes. No fuze was tested more than once.

RESULTS:

I Drop # 1 - 40 Feet - Two of the fuzes indicated no signs of damage or of slider movement. One Fuze: Pull wire had withdrawn approx. 1/8 inch and could not be reseated.

II Drop # 2 - 80 Feet - Same as Drop # 1.

III Drop # 3 - 100 Feet - Same as Drop # 1

IV Drop # 4 - 100 Feet - None of the fuzes indicated any signs of damage or of slider movement

V Drop # 5 - 100 Feet

Two fuzes: Same as Drop # IV
One fuze: Slight slider movement before pull wire was withdrawn. Slight additional slider movement after pull wire was withdrawn. No portion of detonator visible.

SEQUENTIAL ROUGH HANDLING TEST

Fuze, PD, M527B1, M526
USATECOM Project No. 8-MU-007-52C-002
Report No. - APG-MT-3427 (Dec 1969) - G. Shandle
Date of Test: 10 October 1969

M527B1 and M526 fuzes were tested as control samples for the Product Improvement Test of the M525A2E2, M526A2E2, and M527A2E2 fuzes (PYRO-HEAD). Test conducted at APG in accordance with the attached schedule.

RESULTS AFTER 5 FOOT BASE DROP

	60MM	81MM
Qty Tested	48	48
Unserviceable Fuzes	12	12
Unserviceable Ctgs	6	1
No. Fired	30	35
No. Fail to Function	6	4

According to the Test Report, determination of whether a fuze was unserviceable was based only upon external damage. There was no attempt made to determine whether any head assembly had armed.

SEQUENTIAL ROUGH HANDLING TEST (60MM)

XM935 Fuzes, Group II - Short Pull Wire
Date of Test 10 - 11 October 1975

160 Fuzes subjected to Sequential Rough Handling Test. A total of 5 fuzes were found to be armed (Detonator fully in line with booster lead hole). All 5 armed fuzes were found in the armed condition at the conclusion of the test. (5 Foot Base Drop Test). No fuzes were found during the intermediate inspection phases of the test series. The armed fuzes had been subjected to the following test schedule:

Fuze No.	Conditioning Temp.	Loose Cargo Orientation	1st Base Drop Orientation	2nd Base Drop Orientation
21	+145^{o}F	Horizontal	Base Down	Side Down
141	+145^{o}F	Horizontal	Side Down	Base Down
152	+145^{o}F	Horizontal	Nose Down 45^{o}	Base Down 45^{o}
165	+145^{o}F	Vertical	Side Down	Base Down 45^{o}
229	+145^{o}F	Horizontal	Side Down	Side Down

NOTE: In all base drops, except the Nose Down and the Base Down orientations, the fuze was oriented with the selector cap up. (Worst Orientation).

SEQUENTIAL ROUGH HANDLING TEST (60MM)

XM935 Fuze, Group I - Long Pull Wire
LA PA-E-09784 (Original Lot # BWV 2-2)
Date of Test 27 - 29 Sept 1975

160 Fuze subjected to Sequential Rough Handling Test. None of the Sliders moved to the fully armed position, and in no case was any portion of the detonator visible when viewed through the booster lead hole.

11 fuzes were torn down for microphotography. The remaining 149 fuzes were checked for slider retention. The pull wires were withdrawn and the slider movement was observed through the booster lead hole. In 58 of the fuzes, the slider moved slightly as the pull wire was withdrawn. In no cases was any portion of the detonator visible.

NOTE: In all bare drops, except the Nose Down and the Base Down orientations, the fuze was oriented with the selector cap up (Worst Orientation).

ENGINEER: M. Della Terza

LAB: ADGED, FEB, Mortar Sec

REVIEWED BY:

DATE: 6 Oct 75

ITEM: FUZE, PD, M567

TEST NO: 007

TEST OBJECTIVE:

Test the ability of the M567 Fuze with ribbed Delay Holder and six-nibbed Spacer to pass the Mil-Std Sequential Rough Handling test with the fuze's Pull-Wire and Firing Pin safety systems subverted.

CONCLUSIONS AND RECOMMENDATIONS:

The M53 Delay Element will independently prevent arming of the M567 Fuze incorporating the six-nibbed Spacer and the ribbed Delay Holder when the fuze is subjected to the Mil-Std Sequential Rough Handling Test.

BACKGROUND:

This testing is a part of the M567/M935 Malfunction investigation.

DESCRIPTION OF MATERIAL:

1. M567 Front Body Assembly less Lead Assembly and incorporating the six-nibbed Spacer, Dwg 9246254 REV B, and the ribbed Delay Holder, Dwg 9246247 REV E, as per Contract DAAA21-C-76-0059. Also, Firing Pin Tips were ground off.

2. Empty Rear Bodies.

3. Projectile Inert, Lot PAE 90489

4. Pin Assembly XM170, #10551892

5. Package Material:

   a. Fillers Top F/Box Wood F/81mm 15 5/16 x 12 9/16

   b. Stop Pkdg F/81mm Lot BAC 2-9.

   c. Spacer Clipboard F/81mm Lot PNE 22-9

   d. Container Ammo Fiber M252A3 Lot UAC Mixed

   e. Cushion Padding Matl Resilient Type 1 or 2 F/81mm

   f. Filler Disc Assy F/81mm Lot PCC 12-3

   g. Box Packing Ammo

DATA:

M567 Sequential Rough Handling Test

7 Foot Drop (-50°F)

Packing Box Orientation		Fuze Arrangement (nose direction indicated by arrow tip)	
SIDE		←123 188→ ←108 (IMPACT)	
END	(IMPACT)	←119 184→ ←148	
END		←149 114→ ←134	(IMPACT)
FLAT		← 29 138→ ←185	
45°END	(IMPACT)	←133 106→ ← 50	
45°END		← 47 39→ ←166	(IMPACT)
6 ORIENTATIONS		← 20 64→ ← 19	
6 ORIENTATIONS		← 28 111→ ← 8	

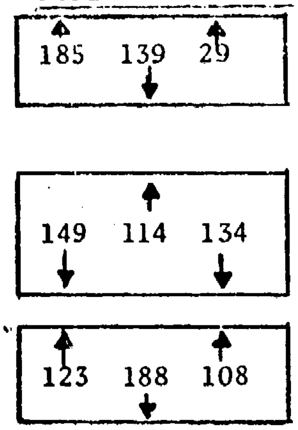
Packing Box Orientation	Fuze Arrangement
Side	(IMPACT) ← 9 145 → ← 183
End	← 142 71 → (IMPACT) ← 53
End	22 → (IMPACT) ← 34 137 →
FLAT	← 4 125 → ← 30
45°END	← 1 144 → (IMPACT) ← 139
45°END	← 38 (IMPACT) 40 → ← 199
6 Orientation	← 54 120 → ← 182
6 Orientation	← 48 10 → ← 65

Bump Test (50°F)

Packing Box Orientation

Vertical

FUZE ARRANGEMENT

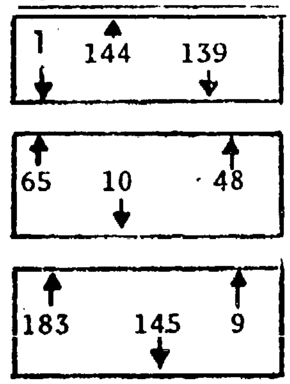


Bump Test (+145°F)

Packing Box Orientation

Vertical

FUZE ARRANGEMENT



DATA CONTINUED:

M567 Sequential Rough Handling Test

5 ft Unpackaged Drop Test

Group I ($-50^{o}F$)

Fuze #	Fuze Orientation	Pull Wire Insertion After Test	Remarks
39	NOSE	YES	
134	NOSE	YES	
19	NOSE	YES	
20	BASE	YES	
133	BASE	YES	
64	BASE	YES	
166	HORIZONTAL	NO	PARTIAL SLIDER MOVEMENT
149	HORIZONTAL	YES	
185	HORIZONTAL	YES	
106	45^{o} BASE	YES	
119	45^{o} BASE	YES	
29	45^{o} BASE	YES	
47	45^{o} NOSE	YES	
138	45^{o}NOSE	YES	
114	45^{o} NOSE	YES	

GROUP II (+145°F)

FUZE #	FUZE ORIENTATION	PULL WIRE INSERTION AFTER TEST	REMARKS
199	NOSE	YES	
40	NOSE	YES	
137	NOSE	YES	
22	BASE	YES	
71	BASE	YES	
30	BASE	YES	
38	HORIZONTAL	NO	PARTIAL SLIDER MOVEMENT
34	HORIZONTAL	NO	
183	HORIZONTAL	YES	
4	45° BASE	YES	
144	45° BASE	YES	
48	45° BASE	NO	PSM
139	45° NOSE	NO	PSM
9	45° NOSE	YES	
1	45° NOSE	YES	

M567

Rough Handling Test (NO PULL WIRES and Ground Off Firing Pin Tips)

Visual Exam: After Horizontal Bump - Cold (#1 12)
After Vertical Bump - Cold (#13 21)
After Vert Bump - Hot (#22 30)
After Hroiz Bump - Hot (#31 42)

Fuze #	Safety Pin Insertion	Other Damage	Fuze #	Safety Pin Insertion	Other Damage
148	NO	NONE	144	YES	NONE
119	YES	NONE	10	YES	NONE
50	YES	NONE	183	YES	NONE
184	YES	NONE	139	YES	NONE
106	YES	NONE	48	YES	NONE
47	NO	NONE	145	YES	NONE
133	YES	NONE	199	YES	NONE
64	YES	NONE	40	YES	NONE
19	YES	NONE	22	YES	NONE
20	YES	W.S. DENTED	38	YES	W.S. Partially
39	YES	NONE	137	YES	NONE
166	YES	NONE	125	YES	NONE
138	NO	NONE	71	YES	NONE
29	YES	NONE	142	YES	NONE
185	YES	NONE	34	YES	NONE
114	NO	NONE	30	YES	NONE
134	YES	NONE	53	YES	NONE
149	YES	NONE	4	YES	NONE
108	YES	NONE			
123	YES	NONE			
188	YES	NONE			
9	YES	NONE			
1	YES	NONE			
65	YES	1			

W.S. means Wind Shield

TEST PROCEDURE:

See attached chart "Artillery Ammunition", No rounds were fired. All fuzes were disassembled in Bldg 617.

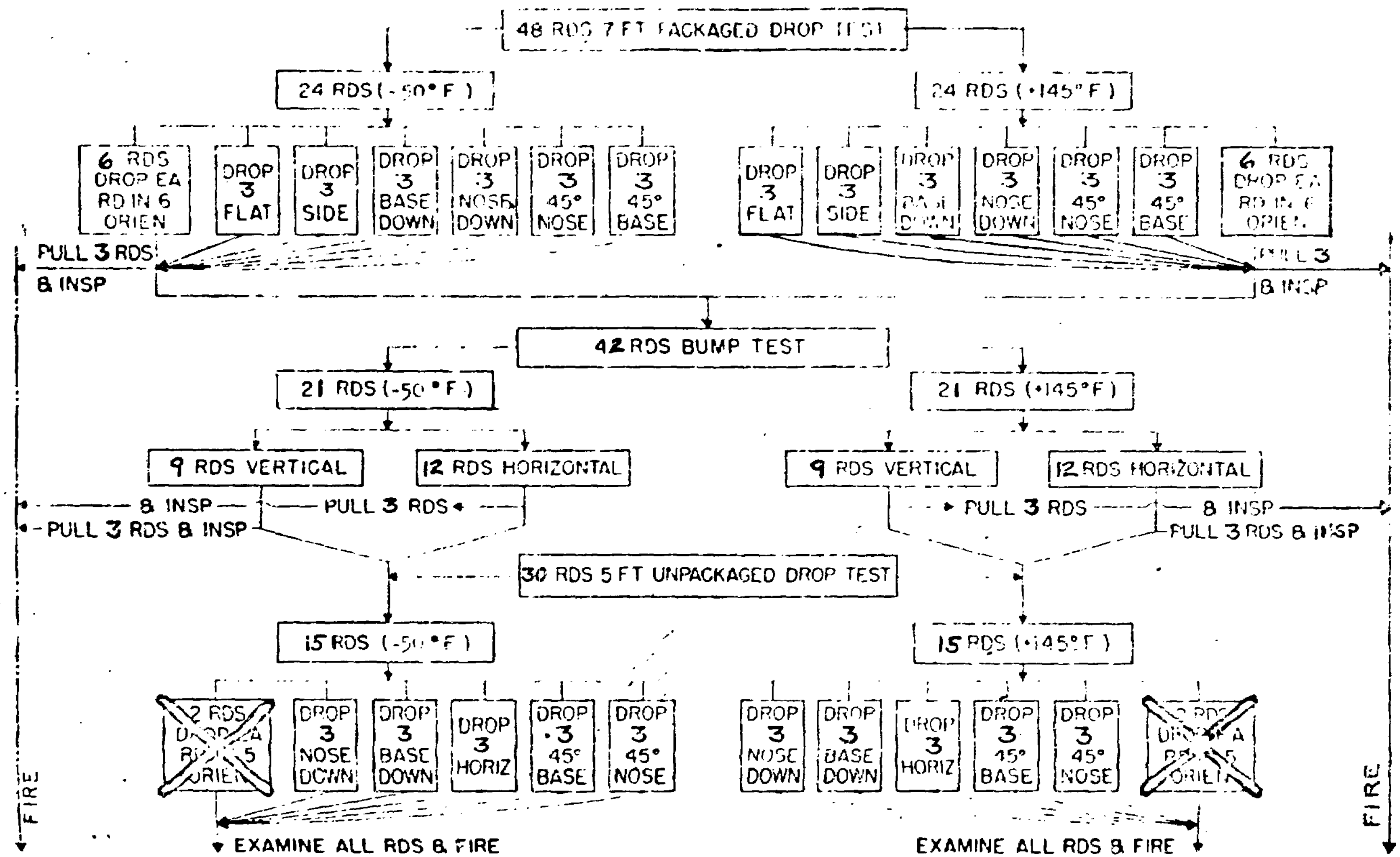
SUMMARY:

Test #007 - Sequentail Rough Hnadling - M567 Fuzes with subverted Pull Wire and Firing Pin Safety Systems and incorporations ribbed Delay Holders and six-ribbed Spacers.

1. No fuzes were armed.

2. Five fuzes exhibited partial slider movement after the five foot drop test.

ARTILLERY AMMUNITION



APPENDIX E

BALLISTIC TESTING

BALLISTIC TESTS

Ballistic tests were conducted to assure that changes in fuze design, essentially firing pin profile would not degrade fuze performance or reliability.

<u>First Ballistic Test</u>

Place: Camp Edwards

Date: 6 November 1975

Fuze: M567, PD

Fuze Modifications: New Delay Element Holder
New Spacer
New One Piece Firing Pin

Projectile: 81MM, M374, Inert

Total Number of Rounds Fired: 126

Charge	Mode	No. Samples	No. Duds	Remarks
Chg. 0	Delay	31	1	3 Surface Burst Function (Short-Time)
Chg. 0	Super Quick	31	1	
Chg. 9	Delay	31	0	15 Surface Burst Function (Short-Time)
Chg. 9	Super Quick	31	0	

<u>Second Ballistic Test</u>

Place: Camp Edwards

Date: 29 December 1975

Fuze: XM935E3

Fuze Modifications: New Delay Element Holder
New Spacer
New Two Piece Firing Pin

Projectile: 81MM, M374 Inert

Charge	Mode	No. Samples	No. Duds	Remarks
Chg. 0	SuperQuick	25	0	
Chg. 0	Delay	25	0	3 Surface Burst Function (Short-Time)
Chg. 9	SuperQuick	25	1	
Chg. 9	Delay	25	0	7 Surface Burst Function (Short-Time)

Results of the two tests conducted showed no substantial degrading of fuze performance or reliability. The only probelm encountered during testing was a number of Surface Bursts Functions, when the fuze was set in the delay mode. The cause of these short times could be inherent in the lot of delay detonators used or due to the firing pin's new profile. Both possibilities are being investigated.

APPENDIX F

XM935 FUZE SUBVERTED SAFETY TEST

BEST AVAILABLE COPY

OBJECTIVE:

To demonstrate that XM935E2 Fuzes with ribbed delay holders and long pullwires are safe for use in DT/OT of the Lightweight Company Mortar.

TEST PHILOSOPHY:

A sample of 300 fuzes will be subjected to rough handling, vibration and drop tests with one safety (the firing pin) subverted.

TEST CRITERIA:

The XM935E2 will be adjudged safe for use in DT/OT II given that no detonations occur in 300 fuzes tested, and that not more than two (2) fuzes arm either immediately or when the pullwire is withdrawn. Any detonator moving a distance great enough to come within .025 inch of the lead assembly (edge to edge) shall be considered armed.

In the event of any fuze failing to pass this criteria, an investigation program will be initiated to determine the cause of failure and to determine if corrective action is required.

TEST PLAN:

1) Select a 300 piece random sample from 3,000 to [illegible] of the 6,000 M567 Fuzes to be delivered to Picatinny. Remove front [illegible] body, firing pin, MS 19060-20 ball, and lead assembly. Inspect fuzes visually and serialize using "T-1" through "T-300". Count components removed from fuzes.

2) Divide fuzes and pretest condition as follows:

a. 150 each HOT COND 12 hours +145^{o}F

b. 150 each COLD COND 12 hours -50^{o}F.

3) See Charts 1, 2 and 3 for testing to be conducted and Inclosures 1 - 6 for test details.

INCLOSURE I

TEST: TRANSPORTATION VIBRATION

PROCEDURE:

1) Using Procedure I, Test 119, MIL-STD-331, Test 10 Fuzes at +145°F and 10 fuzes at -50°F. (No testing at 73°F)

2) Conduct visual inspection of test items.

3) Remove pull wire and reinsert.

4) X-ray fuzes.

5) Record any damage or movement seen on x-ray.

6) Disassemble fuzes, inspect for damage, record and photograph any damage.

CRITERIA FOR PASSING TEST:

See Paragraph 3, Test 119, MIL-STD-331. Any fuze which detonates or arms, either in test or when the pull wire is withdrawn shall be considered to have failed this test.

INCLOSURE II

TEST: JUMBLE

PROCEDURE:

1) Select 10 hot and 10 cold conditioned fuzes.

2) Subject the 20 fuzes to test 102.1 MIL-STD-331.

3) Conduct visual inspection of test items.

4) Remove pull wire and reinsert.

5) X-ray fuzes.

6) Record any damage or movement seen on x-ray.

7) Disassemble fuzes, inspect for damage, record and photograph any damage.

CRITERIA FOR PASSING TEST:

See Paragraph 3, Test 102.1, MIL-STD-331. Any fuze which detonates or arms, either in test or when the pull wire is withdrawn, shall be considered to have failed this test.

INCLOSURE III

TEST: JOLT

PROCEDURE:

1) Select 10 hot and 10 Cold conditioned fuzes.

2) Subject the 20 fuzes to test 101.1, MIL-STD-331 (1750 jolts each orientation).

   a) Fuzes in the Horizontal position to be oriented selector cap up.

3) Conduct visual inspection of test items after each orientation.

4) Test each fuze 16,000 additional jolts in the horizontal position.

   a) Check for tightness to arm each 2,000 jolts.

   b) Any loose fuzes to be removed from test.

5) Remove pull wire and reinsert.

6) X-ray fuzes.

7) Record any damage or movement seen on x-ray.

8) Disassemble fuzes, inspect for damage, record and photograph any damage.

CRITERIA FOR PASSING TEST:

See Paragraph 3, Test 102.1. Any fuze which detonates or arms, either in test or when the pull wire is withdrawn, shall be considered to have failed this test.

INCLOSURE IV

TEST: SEQUENTIAL ROUGH HANDLING (SRH)

PROCEDURE:

1) Select 80 hot conditioned fuzes assembled to XM720 projectiles.

2) Package 8 rounds in each metal can. Place 2 cans in each of 5 boxes.

3) Condition the 5 boxes at +145°F.

4) Repeat 1 and 2 above for cold conditioned fuzes.

5) Condition the 5 boxes at -50°F.

6) Conduct complete SRH test (except ballistic flight test) per CTG-LWCM's DT II.

7) a) Orientation for 5 foot drop test: Code 1 - Side drop, 4 - 45° Base down drop and 5 - 45° nose down drop to be selector cap up.

   b) 1 hot box and 1 cold box removed before loose cargo test to be used in special engineering test no included in this test plan.

8) Conduct visual inspection.

9) Remove pullwire and reinsert.

10) X-ray fuzes.

11) Record any damage or movement seen on x-ray.

12) Disassemble all fuzes, inspect for damage, record and photograph any damage.

CRITERIA FOR PASSING TEST:

See Paragraph 3, Test 111.1 MIL-STD-331. Any fuze which detonates or arms, either in test or when the pullwire is withdrawn, shall be considered to have failed this test.

INCLOSURE V

TEST: FIVE FOOT DROP

PROCEDURE:

1) Select 20 Cold, and 20 Hot Conditioned Fuzes.

2) Assemble the above 40 fuzes to inert 60MM, XM720 Cartridges.

3) Temperature condition the assembled rounds to the temp (+150°F -50°F) which the fuze was previously conditioned for a minimum of 12 hours.

4) Remove pullwire prior to drop.

5) Drop each fuzes projectile from a heightof five feet one time.

   (a) Fuzes to be oriented selector cap up.

6) Reinsert pullwire - record.

7) Remove fuzes from projectile and rear body from front body assembly.

8) Conduct visual inspection of front body assemblies record finding.

9) X-ray fuzes.

10) Record any damage or movement seen on x-ray.

11) Disassemble fuzes, inspect for damage, record and photograph any damage.

CRITERIA FOR PASSING TEST:

See Paragragh 3.1.1, Test 111.1, MIL-STD-331. Any fuze which detonates or arms, either in test or when thepullwire is withdrawn, shall be considered to have failed this test.

INCLOSURE VI

TEST: FORTY FOOT DROP

PROCEDURE:

1) Select 20 cold, 20 hot and conditioned fuzes.

2) Assemble the above 40 fuzes to inert 81mm, M374 projectiles.

3) Temperature condition the assembled rounds to the temp (+145°F or -50°F) which the fuze was previously conditioned for a minimum of 12 hours.

4) Drop each fuzed projectile 40 feet to land in the horizontal position, fuze selector cap up.

5) Remove fuzes from projectile and rear body from front body assembly.

6) Conduct visual inspection.

7) Remove pull wire and reinsert.

8) X-ray fuze.

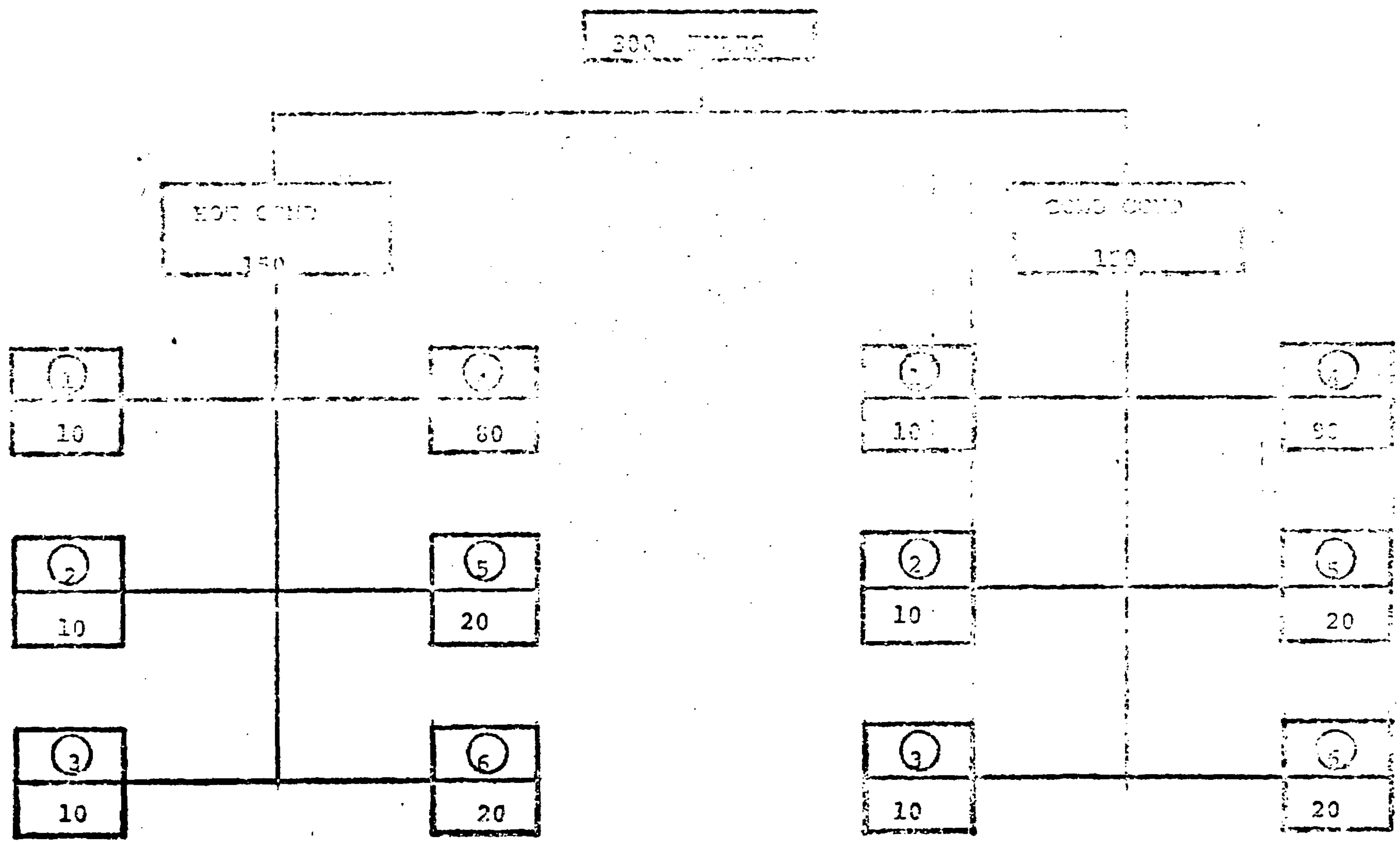
9) Record any damage or movement seen on x-ray.

10) Disassemble fuzes, inspect for any damage, which would make the fuze unsafe to handle and dispose.

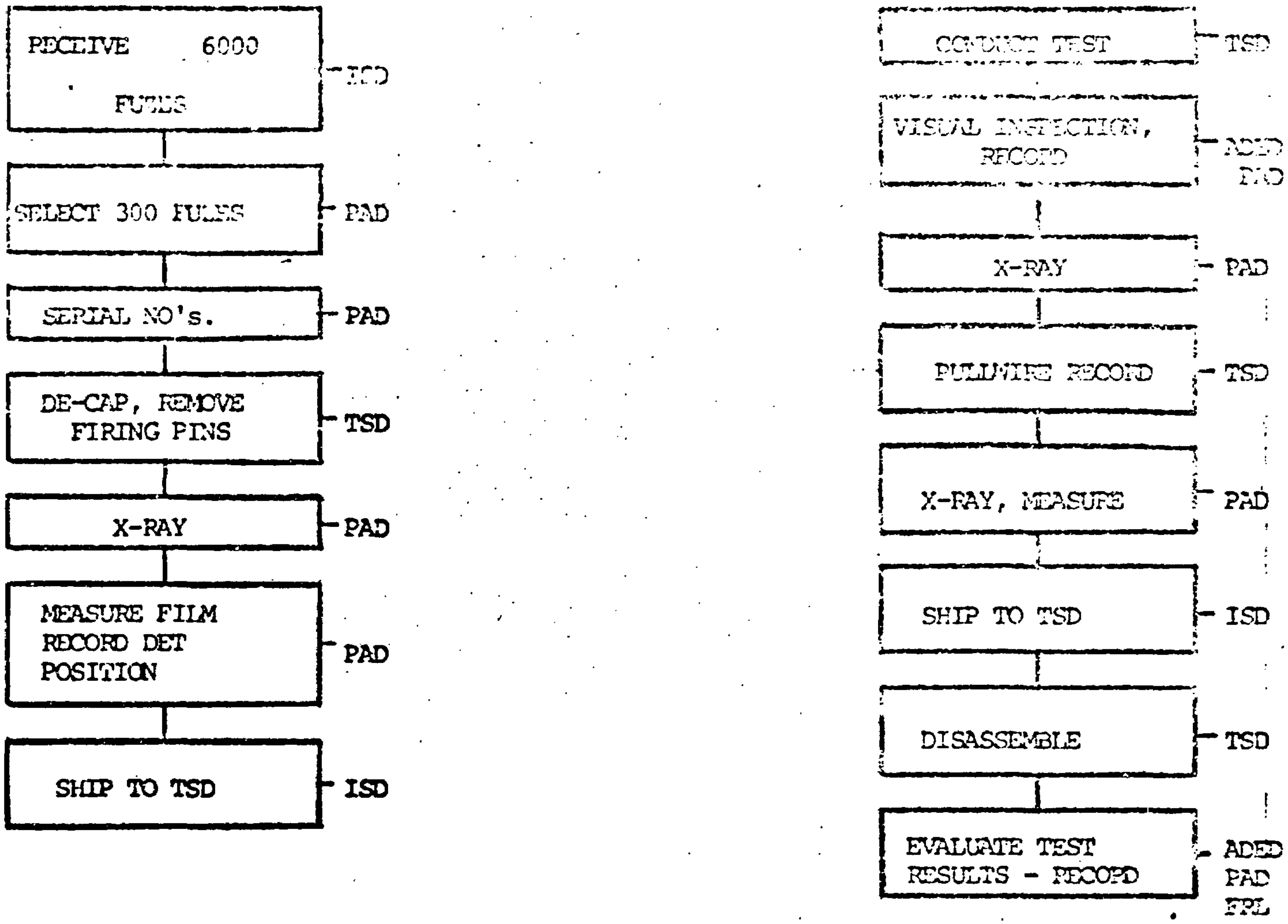
CRITERIA FOR PASSING TEST:

See Paragraph 3, Test 103, MIL-STD-331. Any fuze which detonates or is damaged in such a way to make it unsafe to handle and dispose of following this test shall be considered to have failed this test.

TEST #		HOT	COLD	TOTAL
1	TRANSPORTATION/ VIBRATION @ +145°F -50°F	10	10	20
2	[illegible] @ AMB. [illegible]	10	10	20
3	JOLT @ AMBIENT 10 C C AND [illegible]	10	10	20
4	SRH @ TEMP PULLWIRE X-RAY	80	80	160
5	5' DROP @ TEMP +145°F -50°F WITHOUT PULLWIRE	20	20	40
6	40' DROP @ TEMP +145°F -50°F MEAS, SINGLE DROP	20	20	40
		150	150	300

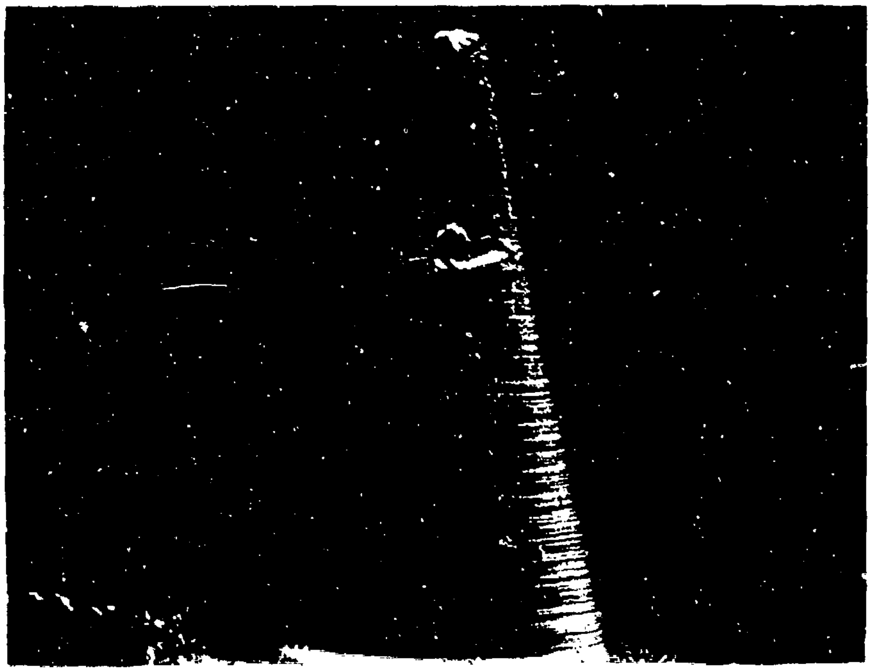

300
10
80
10
20
10
20
10
90
10
20
10
20

FLOW CHART - SPECIAL TEST



APPENDIX G

TEST SPECIMEN PHOTOGRAPHS



TYPICAL FIRING PIN DAMAGE (142)
Fig. F-1

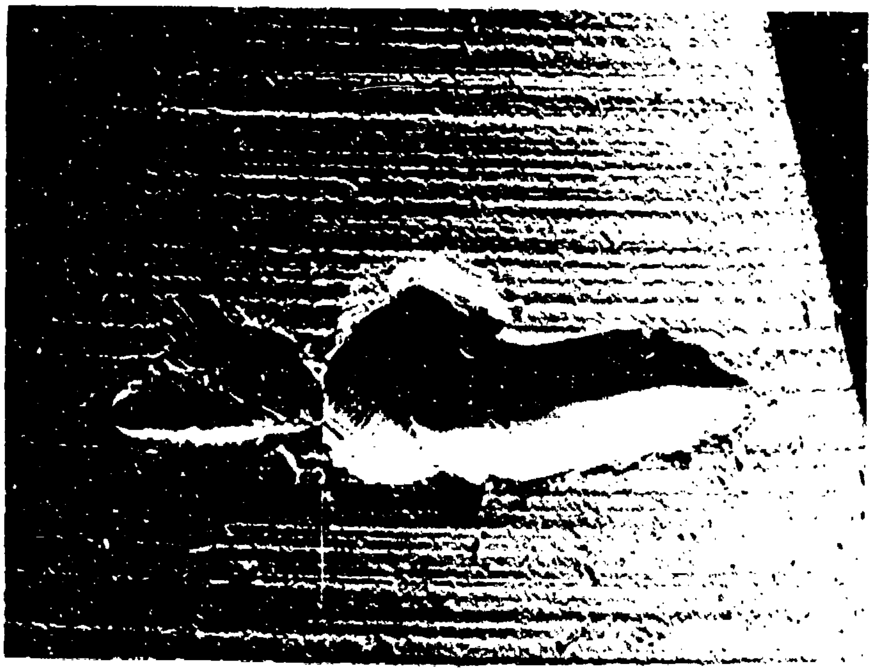
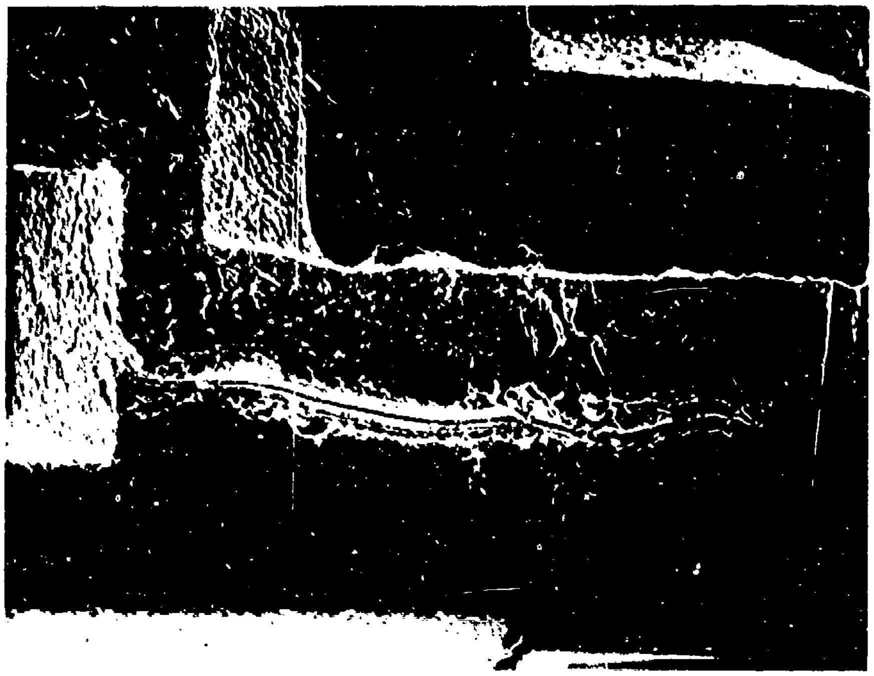


Fig. F-2



SLIDER DAMAGE DUE TO PULL WIRE AND DELAY PIN (21)
SEQUENTIAL ROUGH HANDLING WITH SHORT PULL WIRE
FIG. F-3

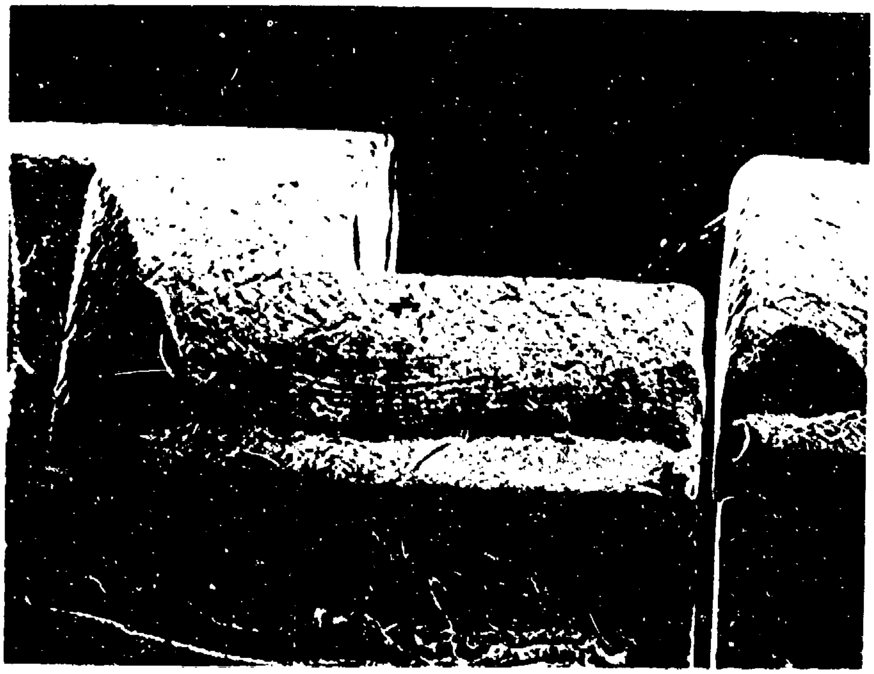
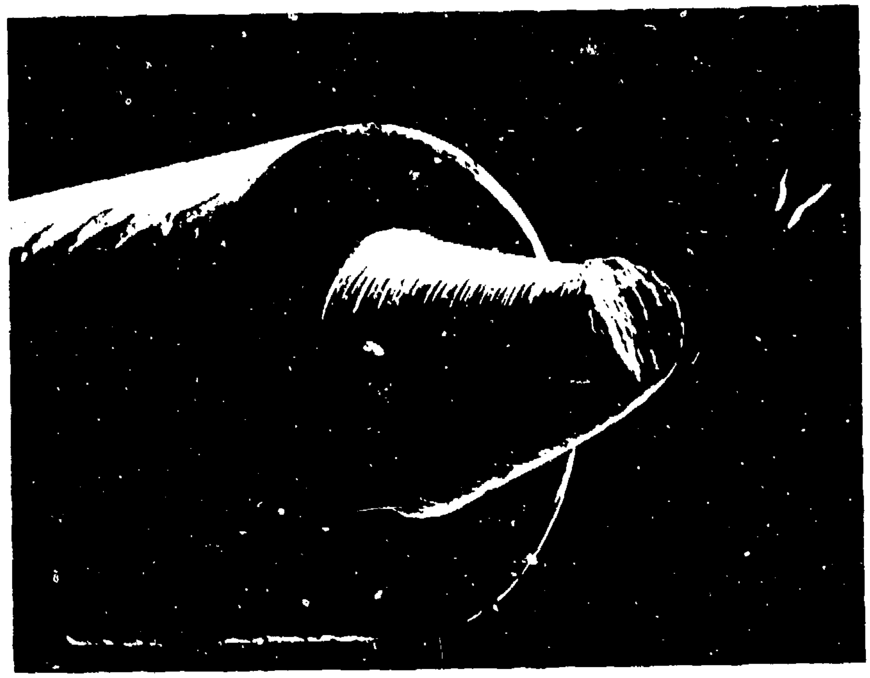


FIG. F-4



SLIDER AND FIRING PIN DAMAGE (21)

SEQUENTIAL ROUGH HANDLING
FIG. F-5

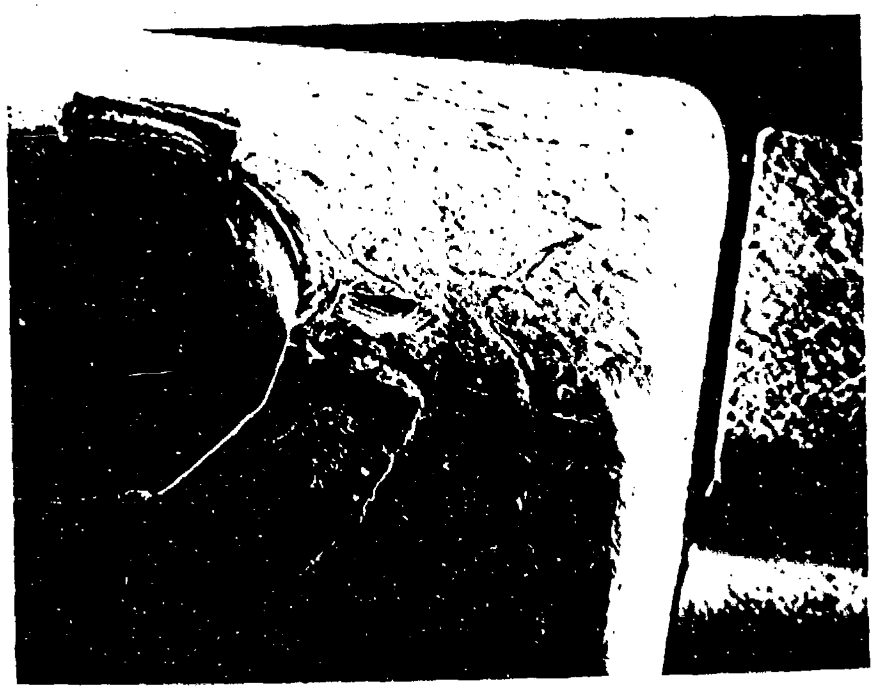
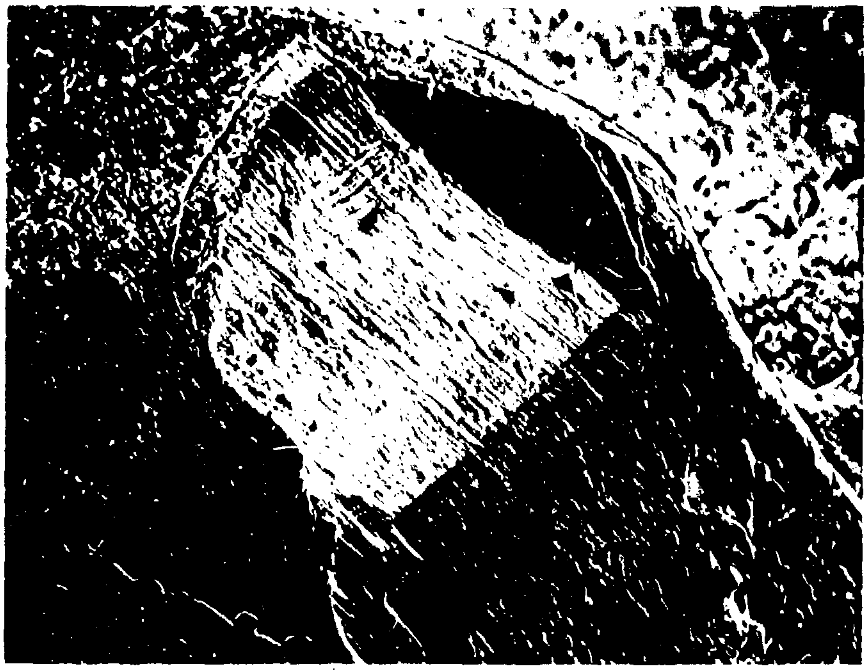


FIG. F-6



SLIDER DAMAGE OF SAFE FUZE (157)
SEQUENTIAL ROUGH HANDLING
FIG. F-7

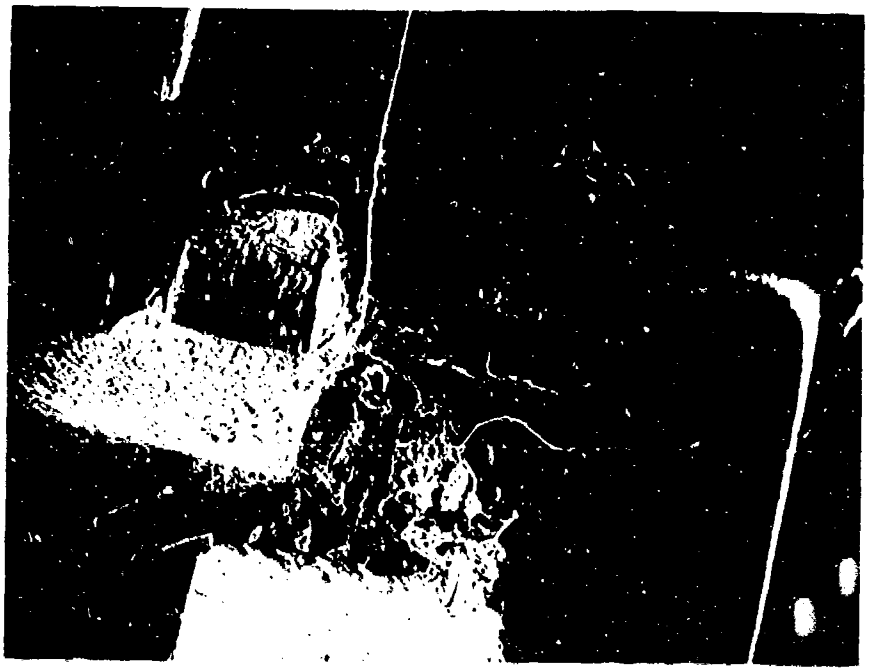
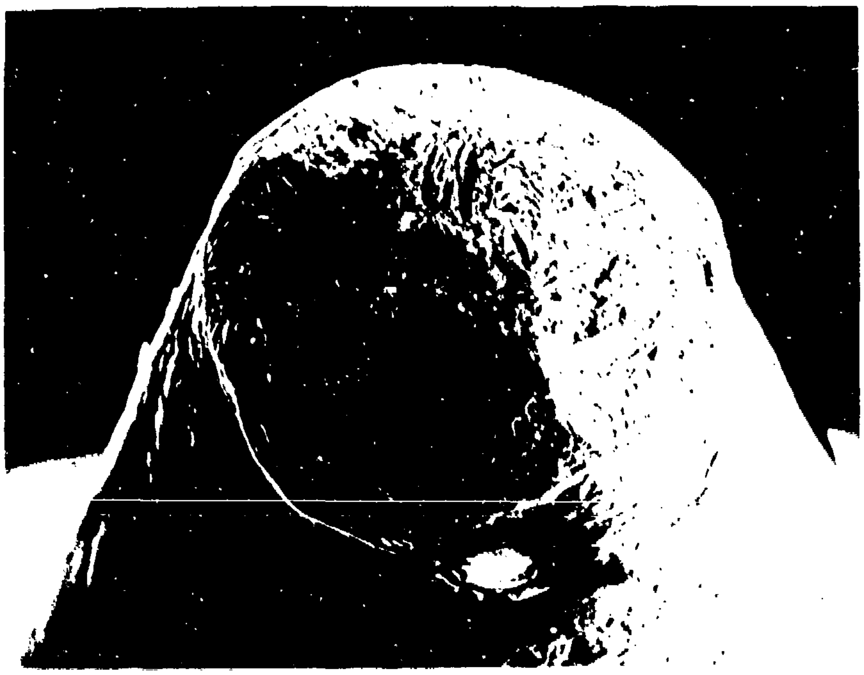


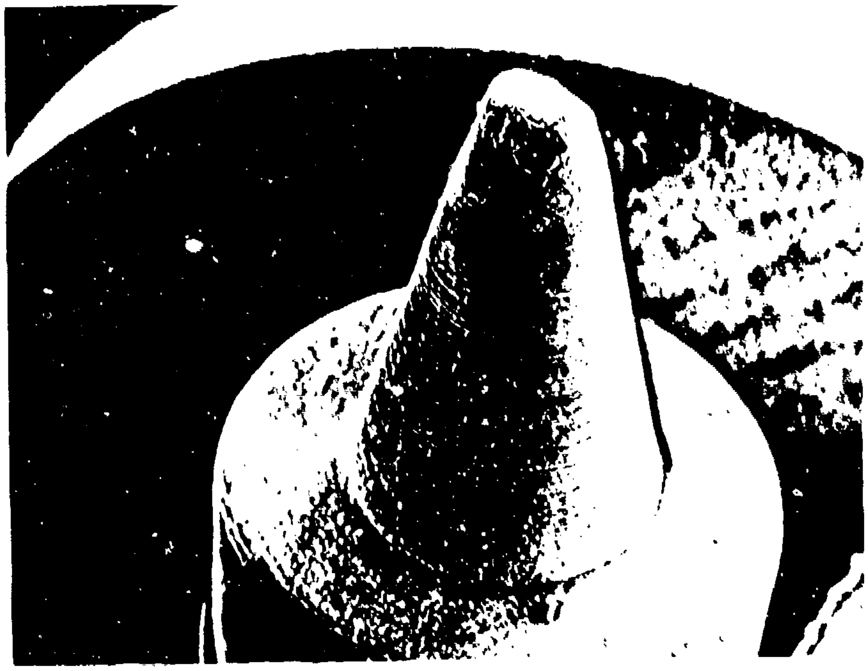
FIG. F-8



FIRING PIN DAMAGE OF SAFE FUZE (157)

SEQUENTIAL ROUGH HANDLING

FIG. F-9



FIRING PIN DAMAGE (16)
JOLT
FIG. F-10

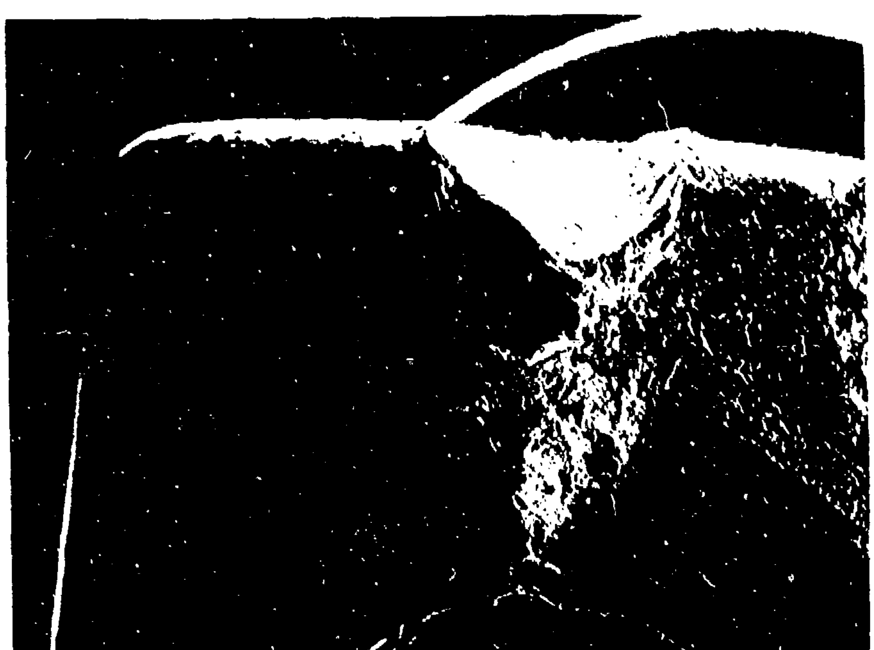


FIG. F-11

JOLT

FIRING PIN DAMAGE (16)

FIG. F-12

DELAY ELEMENT ORIENTATION (16)

FIG. F-13

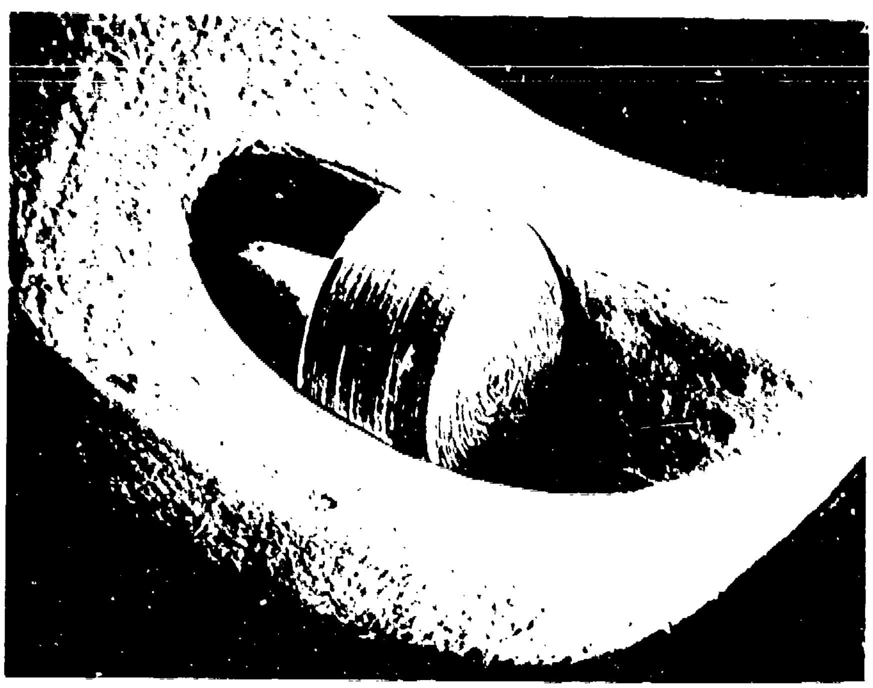
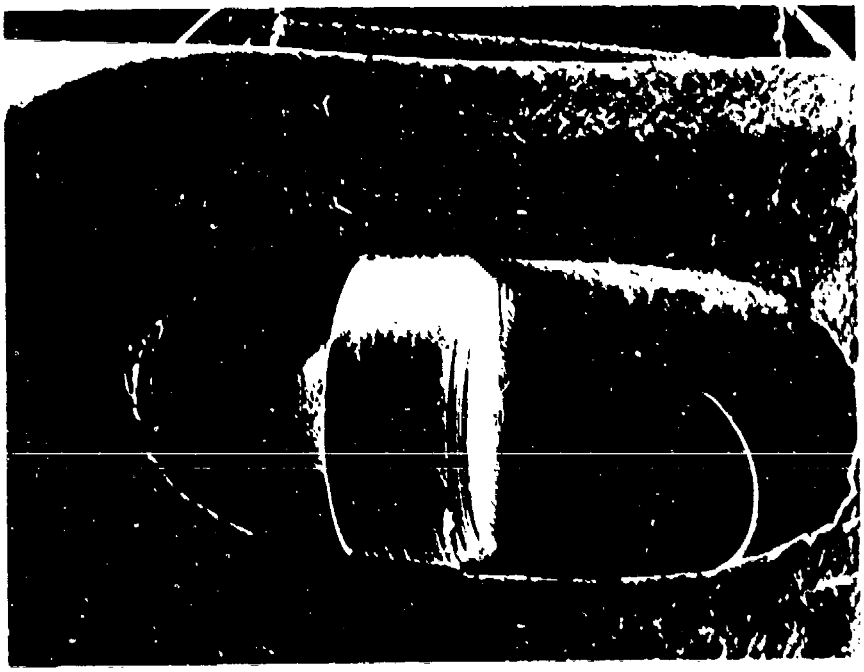


FIG. F-14



DELAY ELEMENT ORIENTATION (16)

FIG. F-15

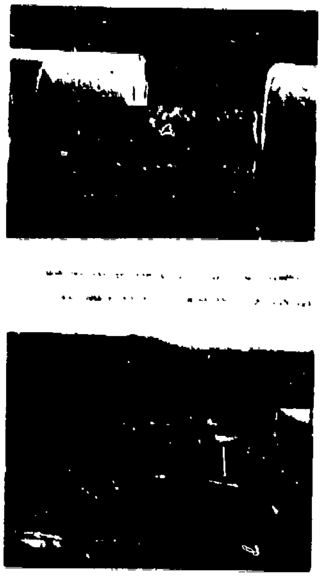


FIG. F-16

FIG. F-17

FIG. F-18

FIG F-19

FIG. F-20

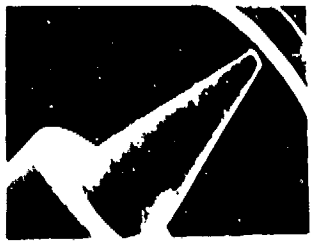


FIG. F-21

FIG F-22

APPENDIX H

SPECIAL "180" SUBVERT SAFETY SEQUENTIAL ROUGH HANDLING TEST

ENGINEER: H. Hoganson FUZE ENGINEERING BRANCH, AD&ED

ITEM: FUZE, PD, M567 DATE: 3 March 1976

TEST OBJECTIVE:

1. To determine if the modifications to the XM935 60MM Fuze for L.W.C.M. System are adequate for the 81MM System.

CONCLUSIONS AND RECOMMENDATIONS:

1. Although one fuze armed of 180 tested at -50°F with the firing pin and pull wire subverted, the results were compatable with testing on the 60MM System.

2. Subsequent modifications to future production hardware will increase the strength of components which failed.

BACKGROUND:

This testing is part of the M567 Malfunction Investigation.

DESCRIPTION OF MATERIAL

1. Fuze assemblies - Lot BWV 4-1
2. Pull wire and firing pins removed.
3. Inert loaded 81MM cartridge with empty M567 rear bodies.
4. Lead assemblies removed
5. Live M53 delay, M98 detonator and M76 delay detonators.
6. Standard 3 cartridge overpack.

DATA: See Inclosure I to this test.

DISCUSSION OF RESULTS:

Examination of test hardware shows the only significant damage occurred on the fuze which armed. This fuze had a broken end plate.

TEST PROCEDURE:

Testing was conducted to the newest 81MM Sequential Rough Handling Test plan (See Inclosure II to this test) at -50°F. Cold temperature has shown to be the most extreme test environment. Each round was oriented with the selector cap up in the overpack and also in unpackaged drops when possible.

SUMMARY OF RESULTS:

1. The one fuze which armed was subjected to the following environments:

   a. Overpack drop on bottom and 45° nose down.
   b. Horizontal bump and nose down bump for 15 min. each.
   c. 5 foot unpackaged drop on its side and 45° base down.

APPENDIX H

INCLOSURE I

81MM SEQUENTIAL ROUGH HANDLING

FUZE NO.		OVERPACK 7' DROP: DROP #1	OVERPACK 7' DROP: DROP #2	VERTICAL BUMP SIDE UP	UNPACKAGED 5' DROP: DROP #1	UNPACKAGED 5' DROP: DROP #2
1	1-1	BOTTOM	BOTTOM	LEFT	----	----
2					SIDE	SIDE
3					SIDE	SIDE
4				RIGHT	----	----
5					SIDE	SIDE
6					SIDE	SIDE
7				LEFT	----	----
8					SIDE	SIDE
9					SIDE	SIDE
10				RIGHT	----	----
11					SIDE	SIDE
12					SIDE	SIDE
13	1-2	BOTTOM	BASE	LEFT	----	----
14			NOSE		SIDE	BASE
15			BASE		BASE	SIDE
16			BASE	RIGHT	----	----
17			NOSE		SIDE	BASE
18			BASE		BASE	SIDE
19			BASE	LEFT	----	----
20			NOSE		SIDE	BASE
21			BASE		BASE	SIDE
22			BASE	RIGHT	----	----
23			NOSE		SIDE	BASE
24			BASE		BASE	SIDE
25	1-3	BOTTOM	NOSE	LEFT	----	----
26			BASE		SIDE	NOSE
27			NOSE		NOSE	SIDE
28			NOSE	RIGHT	----	----
29			BASE		SIDE	NOSE
30			NOSE		NOSE	SIDE
31		BOTTOM	NOSE	LEFT	----	----
32			BASE		SIDE	NOSE
33			NOSE		NOSE	SIDE
34			NOSE	RIGHT	----	----
35			BASE		SIDE	NOSE
36			NOSE		NOSE	SIDE
37	1-4	BOTTOM	45° BASE	LEFT	----	----
38			45° NOSE		SIDE	45° BASE
39			45° BASE		45° BASE	SIDE
40			45° BASE	RIGHT	----	----
41			45° NOSE		SIDE	45° BASE
42			45° BASE		45° BASE	SIDE
43			45° BASE		----	----
44			45° NOSE		SIDE	45° BASE ARMED
45			45° BASE		45° BASE	SIDE
46			45° BASE	LEFT	----	----
47			45° NOSE		SIDE	45° BASE
48			45° BASE		45° BASE	SIDE

INCLOSURE I

81MM SEQUENTIAL ROUGH HANDLING
(Continued)

FUZE NO.		OVERPACK 7' DROP: DROP #1	OVERPACK 7' DROP: DROP #2	VERTICAL BUMP SIDE UP	UNPACKAGED 5' DROP: DROP #1	UNPACKAGED 5' DROP: DROP #2
49	1-5	BOTTOM	45° NOSE	RIGHT	----	----
50			45° BASE		SIDE	45° NOSE
51			45° NOSE		45° NOSE	SIDE
52			45° NOSE	LEFT	----	----
53			45° BASE		SIDE	45° NOSE
54			45° NOSE		45° NOSE	SIDE
55			45° NOSE	RIGHT	----	----
56			45° BASE		SIDE	45° NOSE
57			45° NOSE		45° NOSE	SIDE
58			45° NOSE	LEFT	----	----
59			45° BASE		SIDE	45° NOSE
60			45° NOSE		45° NOSE	SIDE
61	2-2	BASE	BASE	LEFT	----	----
62		NOSE	NOSE		BASE	BASE
63		BASE	BASE		BASE	BASE
64		BASE	BASE		----	----
65		NOSE	NOSE		BASE	BASE
66		BASE	BASE		BASE	BASE
67		BASE	BASE		----	----
68		NOSE	NOSE		BASE	BASE
69		BASE	BASE		BASE	BASE
70		BASE	BASE	RIGHT	----	----
71		NOSE	NOSE		BASE	BASE
72		BASE	BASE		BASE	BASE
73	2-3	BASE	NOSE	LEFT	----	----
74		NOSE	BASE		BASE	NOSE
75		BASE	NOSE		NOSE	BASE
76		BASE	NOSE		----	----
77		NOSE	BASE		BASE	NOSE
78		BASE	NOSE		NOSE	BASE
79		BASE	NOSE	RIGHT	----	----
80		NOSE	BASE		BASE	NOSE
81		BASE	NOSE		NOSE	BASE
82		BASE	NOSE	LEFT	----	----
83		NOSE	BASE		BASE	NOSE
84		BASE	NOSE		NOSE	BASE
85	2-4	BASE	45° BASE	RIGHT	----	----
86		NOSE	45° NOSE		BASE	45° BASE
87		BASE	45° BASE		45° BASE	BASE
88		BASE	45° BASE	LEFT	----	----
89		NOSE	45° NOSE		BASE	45° BASE
90		BASE	45° BASE		45° BASE	BASE
91	2-4	BASE	45° BASE	RIGHT	----	----
92		NOSE	45° NOSE		BASE	45° BASE
93		BASE	45° BASE		45° BASE	BASE

INCLOSURE 1

81MM SEQUENTIAL ROUGH HANDLING
(Continued)

	OVERPACK 7' DROP				UNPACKAGED 5' DROP	
FUZE NO.		DROP #1	DROP #2	VERTICAL BUMP SIDE UP	DROP #1	DROP #2
94	2-4	BASE	45° BASE	LEFT	----	----
95		NOSE	45° NOSE		BASE	45° BASE
96		BASE	45° BASE		45° BASE	BASE
97	2-5	BASE	45° NOSE		----	----
98		NOSE	45° BASE		BASE	45° NOSE
99		BASE	45° NOSE		45° NOSE	BASE
100		BASE	45° NOSE	RIGHT	----	----
101		NOSE	45° BASE		BASE	45° NOSE
102		BASE	45° NOSE		45° NOSE	BASE
103		BASE	45° NOSE	LEFT	----	----
104		NOSE	45° BASE		BASE	45° NOSE
105		BASE	45° NOSE		45° NOSE	BASE
106		BASE	45° NOSE	RIGHT	----	----
107		NOSE	45° BASE		BASE	45° NOSE
108		BASE	45° NOSE		45° NOSE	BASE
109	3-3	NOSE	NOSE	RIGHT	----	----
110		BASE	BASE		NOSE	NOSE
111		NOSE	NOSE		NOSE	NOSE
112		NOSE	NOSE	LEFT	----	----
113		BASE	BASE		NOSE	NOSE
114		NOSE	NOSE		NOSE	NOSE
115		NOSE	NOSE	RIGHT	----	----
116		BASE	BASE		NOSE	NOSE
117		NOSE	NOSE		NOSE	NOSE
118		NOSE	NOSE	LEFT	----	----
119		BASE	BASE		NOSE	NOSE
120		NOSE	NOSE		NOSE	NOSE
121	3-4	NOSE	45° BASE	RIGHT	----	----
122		BASE	45° NOSE		NOSE	45° BASE
123		NOSE	45° BASE		45° BASE	NOSE
124		NOSE	45° BASE		----	----
125		BASE	45° NOSE		NOSE	45° BASE
126		NOSE	45° BASE		45° BASE	NOSE
127		NOSE	45° BASE		----	----
128		BASE	45° NOSE		NOSE	45° BASE
129		NOSE	45° BASE		45° BASE	NOSE
130		NOSE	45° BASE	LEFT	----	----
131		BASE	45° NOSE		NOSE	45° BASE
132		NOSE	45° BASE		45° BASE	NOSE
133	3-5	NOSE	45° NOSE	RIGHT	----	----
134		BASE	45° BASE		NOSE	45° NOSE
135		NOSE	45° NOSE		45° NOSE	NOSE
136		NOSE	45° NOSE	LEFT	----	----
137		BASE	45° BASE		NOSE	45° NOSE
138		NOSE	45° NOSE		45° NOSE	NOSE

INCLOSURE I

81MM SEQU TIAL ROUGH HANDLING
(Continued)

FUZE NO.	OVERPACK 7' DROP			VERTICAL BUMP SIDE UP	UNPACKAGED 5' DROP	
		DROP #1	DROP #2		DROP #1	DROP #2
139	3-5	NOSE	45° NOSE	RIGHT	----	----
140		BASE	45° BASE		NOSE	45° NOSE
141		NOSE	45° NOSE		45° NOSE	NOSE
142		NOSE	45° NOSE	LEFT	----	----
143		BASE	45° BASE		NOSE	45° NOSE
144		NOSE	45° NOSE		45° NOSE	NOSE
145	4-4	45° BASE	45° BASE	LEFT	----	----
146		45° NOSE	45° NOSE		45° BASE	45° BASE
147		45° BASE	45° BASE		45° BASE	45° BASE
148		45° BASE	45° BASE	RIGHT	----	----
149		45° NOSE	45° NOSE		45° BASE	45° BASE
150		45° BASE	45° BASE		45° BASE	45° BASE
151	4-4	45° BASE	45° BASE	LEFT	----	----
152		45° NOSE	45° NOSE		45° BASE	45° BASE
153		45° BASE	45° BASE		45° BASE	45° BASE
154		45° BASE	45° BASE	RIGHT	----	----
155		45° NOSE	45° NOSE		45° BASE	45° BASE
156		45° BASE	45° BASE		45° BASE	45° BASE
157	4-5	45° BASE	45° NOSE	LEFT	----	----
158		45° NOSE	45° BASE		45° NOSE	45° BASE
159		45° BASE	45° NOSE		45° BASE	45° NOSE
160		45° BASE	45° NOSE	RIGHT	----	----
161		45° NOSE	45° BASE		45° NOSE	45° BASE
162		45° BASE	45° NOSE		45° BASE	45° NOSE
163		45° BASE	45° NOSE	LEFT	----	----
164		45° NOSE	45° BASE		45° NOSE	45° BASE
165		45° BASE	45° NOSE		45° BASE	45° NOSE
166		45° BASE	45° NOSE	RIGHT	----	----
167		45° NOSE	45° BASE		45° NOSE	45° BASE
168		45° BASE	45° NOSE		45° BASE	45° NOSE
169	5-5	45° NOSE	45° NOSE	RIGHT	----	----
170		45° BASE	45° BASE		45° NOSE	45° NOSE
171		45° NOSE	45° NOSE		45° NOSE	45° NOSE
172		45° NOSE	45° NOSE		----	----
173		45° BASE	45° BASE		45° NOSE	45° NOSE
174		45° NOSE	45° NOSE		45° NOSE	45° NOSE
175		45° NOSE	45° NOSE		----	----
176		45° BASE	45° BASE		45° NOSE	45° NOSE
177		45° NOSE	45° NOSE		45° NOSE	45° NOSE
178		45° NOSE	45° NOSE	LEFT	----	----
179		45° BASE	45° BASE		45° NOSE	45° NOSE
180		45° NOSE	45° NOSE		45° NOSE	45° NOSE

INCLOSURE II

ORIENTATION 45 ctgs (15 boxes) 7' Pkg'd Drop Test 2 drops/Ctg

DROP NO. 1 →	1	1	1	1	1	2	2	2	2	3	3	3	4	4	5
DROP NO. 2 →	1*	2	3	4	5	2*	3	4	5	3*	4	5	4*	5	5*

(See Code Below)

INSPECT DESIGNATED ROUNDS (*)
(If acceptable, replace in original location and resume matrix)

HORIZONTAL PACKAGED LOOSE-CARGO TEST

VERTICAL PACKAGED LOOSE-CARGO TEST

INSPECT

5-FOOT UNPACKAGED DROP, 2 DROPS PER CARTRIDGE
(One from each original overpack)

5-FOOT UNPACKAGED DROP, 2 DROPS PER CARTRIDGE
(One from each original overpack)

ORIENTATION

← DROP NO. 1	1	2	3	4	5	2	3	4	5	3	4	5	4	5	5
← DROP NO. 2	1	1	1	1	1	2	2	2	2	3	3	3	4	4	5

DROP NO. 1 →	1	1	1	1	1	2	2	2	2	3	3	3	4	4	5
DROP NO. 2 →	1	2	3	4	5	2	3	4	5	3	4	5	4	5	5

INSPECT

FIRE

INSPECT

FIRE

FIRE
(One from each original overpack)

NOTES: 1. Impact surface is 3-inch steel plate supported by at least 18 inches of crushed rock.
2. This test is normally conducted at two temperature extremes, thus requiring 90 samples.
3. Since the loose-cargo tests are conducted in series for this packaging configuration, testing will be limited to 15 minutes in each orientation.

DROP ORIENTATION CODE

	Packaged	Unpackaged
1.	Bottom	Side
2.	End	Base
3.	Opposite End	Nose
4.	Bottom-End Edge	Base At 45°
5.	Bottom-Opposite End Edge	Nose At 45°

SEQUENTIAL ROUGH-HANDLING TEST FOR ARTILLERY, MORTAR, AND RECOILLESS RIFLE AMMUNITION CARTRIDGES
INDIVIDUALLY PACKAGED (USUALLY FIBER CONTAINER) THREE ITEMS PER OVERPACK

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APPENDIX I

SDR REQUIREMENTS

. The following tabulation provides an evaluation of the ET/ST results against the requirements of the SDR:

Source	Requirements	Remarks
SDR,Para.2b(1)	(Essential) The fuze shall be selectable for superquick or 0.05 sec. delay functioning after impact. The type of action desired shall be selected prior to inserting the ammunition into the weapon.	Met Reqmt. NSB waived.
SDR,Para.2b(2)	(Essential) Delayed arming shall be such as not to degrade maximum tactical effectiveness (mortar minimum range) but not less than 100 meters trajectory distance.	Met Reqmt.
SDR,Para.2b(3)	(Essential) When the fuze is set SQ, functioning shall be as fast as possible and at least prior to the shell body penetrating the target.	Met Reqmt.
SDR,Para.2b(4)	(Essential) The fuze shall be safe and operable after delivery by normal functioning parachute.	Met Reqmt.
SDR,Para.2b(5)	(Essential) The fuze, when in Level A pack or when assembled to a projectile in a Level A pack, shall not detonate, deflagrate or be unsafe to handle or to fire when subjected to delivery by malfunctioning parachute.	Met Reqmt.

Source	Requirement	Remarks
SDR,Para.2b(6)	(Essential) The fuze will be suitable for use, and the non-functioning rate for the fuze should not be greater than 2% (1% desired), under the conditions defined for Climatic Categories 1 through 7, and 8 (Desired) in Chapter 2, Section II, of AR 70-38.	Met Reqmt.
SDR,Para.2b(7)	(Essential) The fuze must function satisfactorily (as per Para. 2b(6)) after storage and transit under conditions defined for Climatic Categories 1 through 7, and 8 (Desired) in Chapter 2, Section II of AR 70-38.	Met Reqmt.
SDR,Para.2b(8)	(Essential) The fuze will meet transit conditions, by air and surface means, as specified in Para. 2.6 of AR 70-38.	Met Reqmt.
SDR,Para.2b(9)	(Essential) The fuze shall have a contour and weight so that it is ballistically interchangeable with existing fuzes for the M362, M370, M374 and M375 81mm Cartridges.	Met Reqmt.
SDR,Para.2b(10)	(Essential) The fuze shall remain in a safe and operable condition during storage in a Level A pack for a period of 10 years (20 years desirable) with no mainten-ance required.	Will meet reqmt based on fuze functioning after 28 day temp-humidity cycle, and jungle wrap of complete round.

Source	Requirement	Remarks
SDR,Para.2b(11)	(Essential) A premature rate no greater than one in 1,000,000 shall be the design objective as well as the objective of the quality assurance and inspection provisions of the Technical Data Package.	Will meet reqmt based on two independent safety features, fault tree analysis and ability of fuze to be fired safely when fully armed.
SDR,Para.2b(12)	(Essential) The fuze shall be waterproof.	Met Reqmt.
SDR,Para.2b(13)	(Essential) No tool other than a common screwdriver shall be required to set the fuze for the desired action. The selection of the action must be reversible and mechanism shall withstand 25 such reversals (without limit desireable). The fuze shall be normally set "superquick". The fuze shall be in a safe condition as delivered in its packing case.	Met Reqmt.
SDR,Para.2b(14)	(Desired) The need for a pull wire will be eliminated.	Reqmt waived. (See App. A) Safe for rough handling & trans w/o pullwire. Pullwire reqd only for malf. para. drop.
SDR,Para.2b(15)	(Desired) No tool shall be required to set the fuze for the desired action.	Met Reqmt.

APPENDIX J

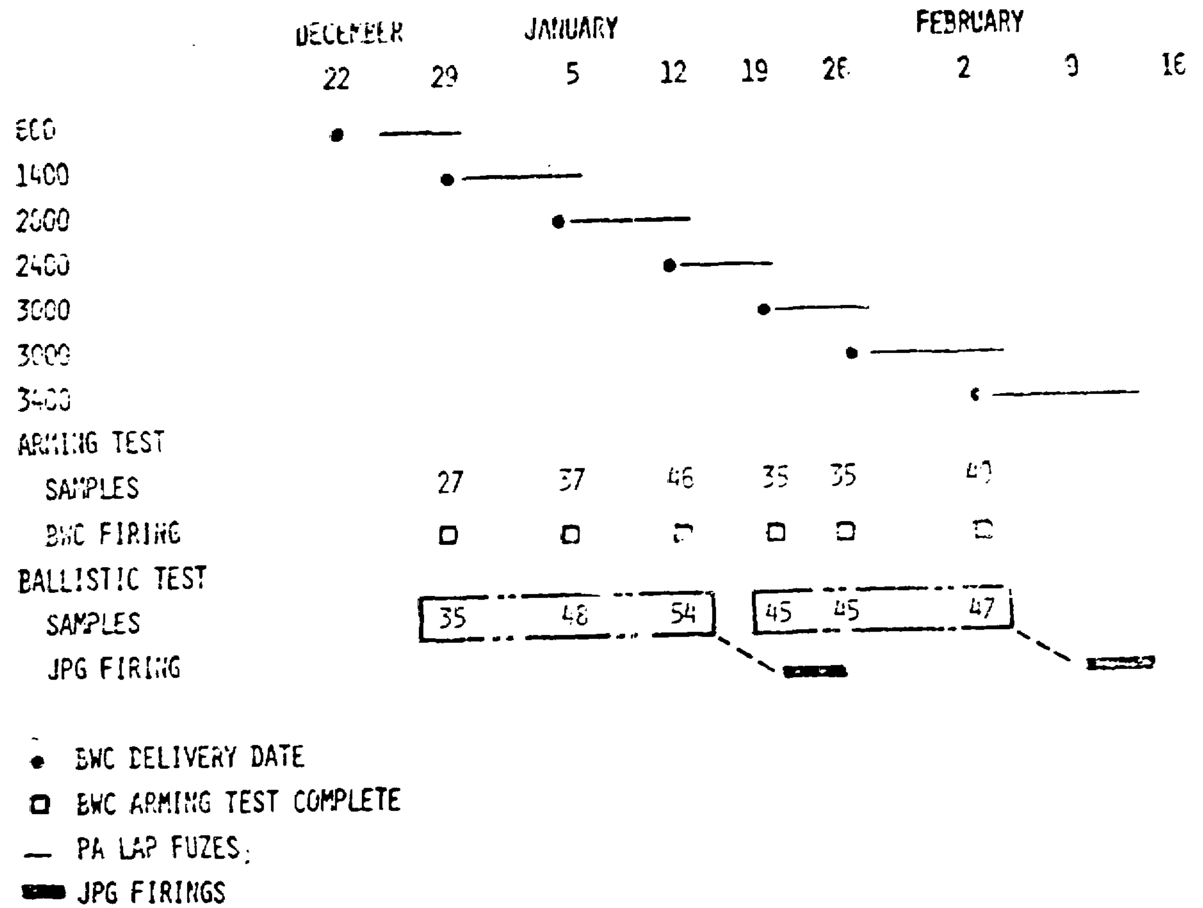
LIGHTWEIGHT COMPANY MORTAR (LWCM)

A 60 mm version of the M567, which has been assigned the number XM935, was provided to the Lightweight Company Mortar (LWCM) program to support their weapon development. In view of the high cost and the relative unavailability of the XM734 MOF (Multi-Option Fuze), it was planned to conduct a large portion of the development and operational testing (DT/OT-II) of the weapon and its ammunition with XM935 fuzes. The fuzes which were supplied to the LWCM program contained the original pull wire which had never been replaced. As a result, in September 1975, a premature attributable to the fuze occurred during the sequential rough-handling test of 160 rounds of 60 mm ammunition at Aberdeen.

The improved XM935 fuze was demonstrated by the 1/300 results of the subverted safety test (see Appendix F) to be fully safe by a large margin. The XM935 also provided the maximum test flexibility and realism in that it could be fired at all charges. As originally planned, the XM935 was to be available for use on the XM720 cartridge to complete DT/OT testing. In order to supply these fuzes, the terminated M567 contract with the Bulova Watch Company was reinstated. Production of over 10,000 XM935 fuzes was completed (based on the merits of the design improvements) and supplied to the LWCM program for completion of testing. All improvements were included in the hardware furnished, except for 6,6000 fuzes which had the one-piece aluminum firing pin and inner bodies which were not pinned. A delivery schedule reflecting the current requirements of the LWCM program were established and adhered to (see Tables 1 through 6). Testing the configuration furnished was accomplished to assure confidence in meeting the safety and functional requirement of this phase of system development.

Table 1

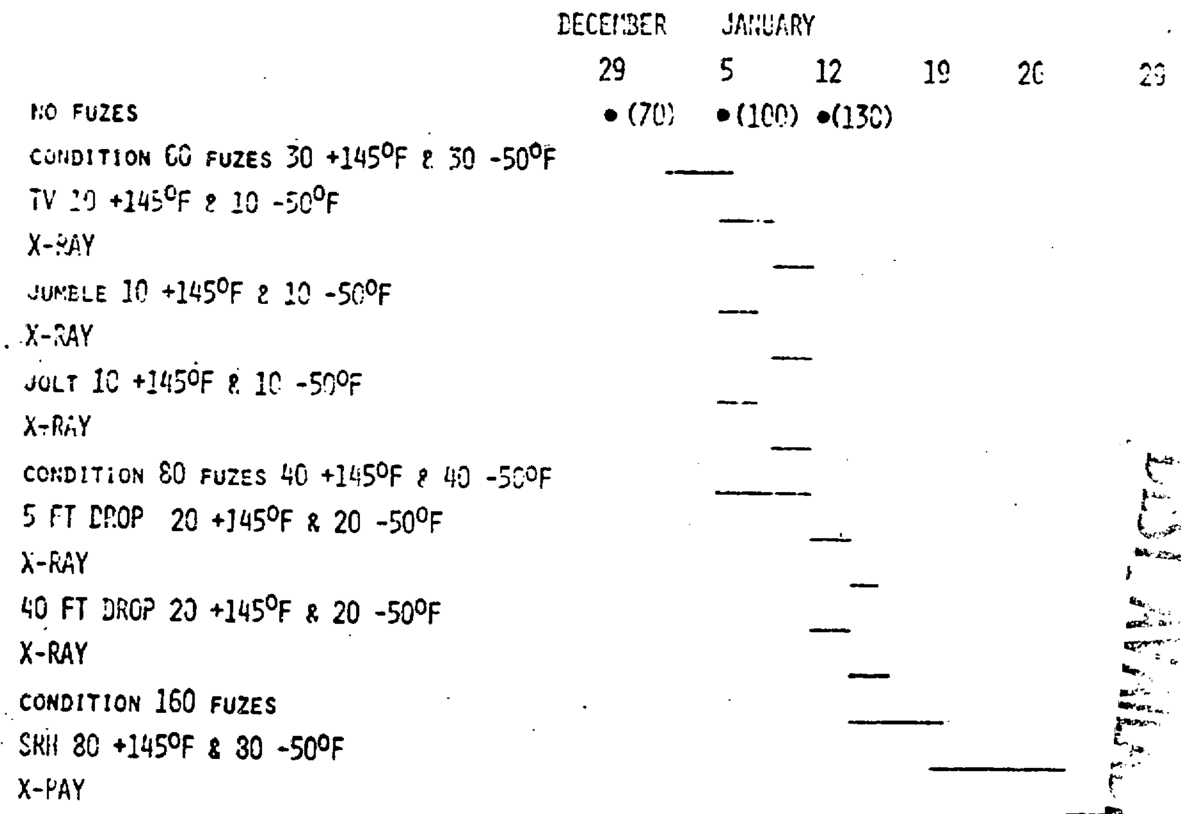
Fuze availability



8 DEC 75

Table 2

300 Subverted safety test



9 DEC 75

Table 3

Ship fuzes and rds

	DECEMBER			JANUARY						FEBRUARY				
	22	25	29	1	5	12	19	26	29	2	9	16	23	29
306 HE RDS APG					●□									
160 INERT APG						●□								
200 FUZES FT. G.								□						
2455 HE RDS FT. B.								●	□					
300 HE W/XM734 FT. B.								●	□					
2745 HE RDS FT. B.											●	□		
2475 INERT APG													●	□

● – SHIPPING DATE
□ – REQ'D DATE

8 DEC 75

Table 4

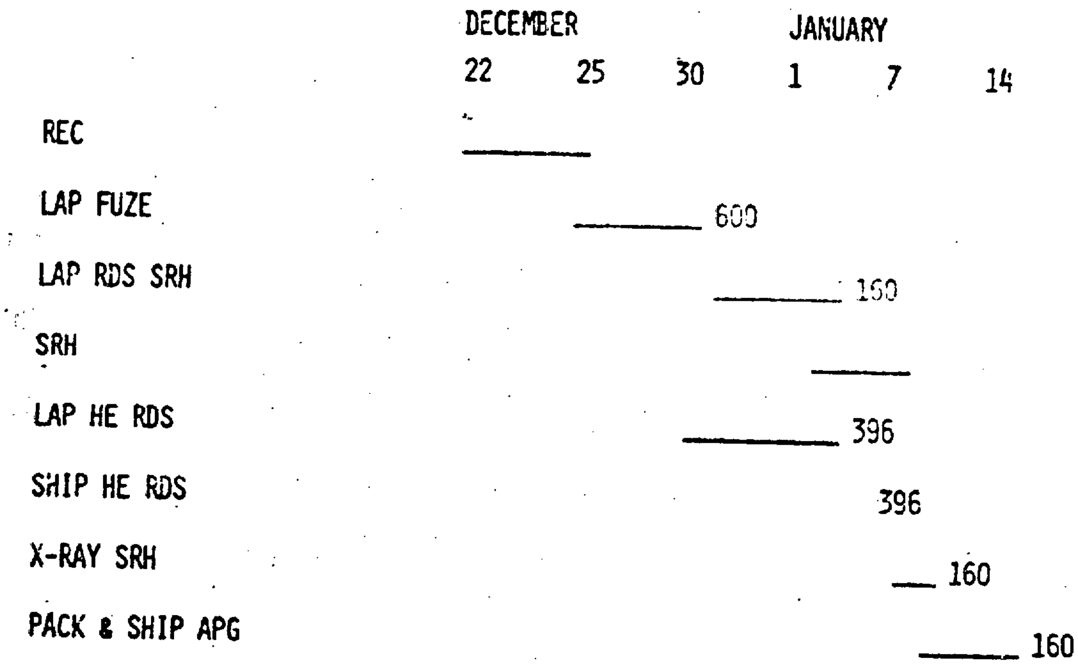
Lap rds w/XM935 fuze

	DEC			JAN						FEB				
	22	25	29	1	5	12	19	26	31	2	9	16	23	29
2455 HE RDS														
2745 HE RDS														
2475 INERT RDS														

8 DEC 75

Table 5

600 APG safety test



8 DEC 75

Table 6

Firing pins to BWC

	DECEMBER 15	22	25	29	JANUARY 1	5	12
ONE PIECE ALUMINUM							
4000	●						
2500		●					
TWO PIECE ALUMINUM & SS							
3000				●			
3000							
3400							

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